GOLDER

REPORT

Kearl Oil Sands Surface Water and Fish Monitoring Plan 2018 Annual Report and Five Year Summary

Imperial Oil Resources Ltd.

Submitted to:

Imperials Oil Resources Limited

Submitted by:

Golder Associates Ltd.

102, 2535 - 3rd Avenue S.E., Calgary, Alberta, T2A 7W5, Canada

18110625

March 2019

Distribution List

1 Electronic Copy - Imperial Oil Resources Limited

1 Electronic Copy - Golder Associates Ltd.

Limitation of Liability, Scope of Report and Third Party Reliance

This report has been prepared and the work referred to in this report has been undertaken by Golder Associates Ltd. for Imperial Oil Limited. It is intended for the sole and exclusive use of Imperial Oil Limited, its affiliated companies and partners and their respective agents, employees and advisors (collectively, "Imperial Oil"). Any use, reliance on or decision made by any person other than Imperial Oil based on this report is the sole responsibility of such other person. Imperial Oil and Golder Associates Ltd. make no representation or warranty to any other person with regard to this report and the work referred to in this report and they accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this report or the work referred to in this report.

The investigation undertaken by Golder Associates Ltd. with respect to this report and any conclusions or recommendations made in this report reflect Golder Associates Ltd.'s judgment based on the site conditions observed at the time of the site inspection on the date(s) set out in this report and on information available at the time of preparation of this report. This report has been prepared for specific application to this site and it is based, in part, upon visual observation of the site, subsurface investigation at discrete locations and depths, and specific analysis of specific chemical parameters and materials during a specific time interval, all as described in this report. Unless otherwise stated, the findings cannot be extended to previous or future site conditions, portions of the site which were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters, materials or analysis which were not addressed. Substances other than those addressed by the investigation described in this report may exist within the site, substances addressed by the investigation may exist in areas of the site not investigated and concentrations of substances addressed which are different than those reported may exist in areas other than the locations from which samples were taken.

If site conditions or applicable standards change or if any additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this report may be necessary.

Other than by Imperial Oil, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of Golder Associates Ltd. Nothing in this report is intended to constitute or provide a legal opinion."

Table of Contents

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

As part of the Kearl Oil Sands development, Imperial Oil Resources Limited has implemented a long-term Surface Water and Fish Monitoring (SWFM) Plan designed to meet the monitoring conditions for aquatic resources specified for Kearl by federal and provincial regulatory agencies. The SWFM Plan addresses monitoring requirements specified by Fisheries and Oceans Canada (DFO) in the Kearl *Fisheries Act* Authorization, and portions of the EPEA Approval that relate to the Kearl habitat compensation plan and to hydrology/climate monitoring. The annual monitoring program has been in operation since 2009. This report provides the results of the 2018 component of the monitoring program as well as specific analytical results from the 2017 monitoring program that were not available for previous reports. In addition to annual monitoring reports, a summary of the overall monitoring results and integration of the Kearl monitoring data with regional monitoring data occurs every five years of the program. As 2018 marks the tenth year of the monitoring program, this report provides the second five-year summary report.

The long-term SWFM Plan was designed to monitor for potential effects of Kearl on the aquatic environment within and adjacent to the Kearl area and evaluate the effectiveness of fish habitats constructed to provide compensation for habitats affected by Kearl development. The long-term monitoring plan includes monitoring of three environmental components: 1) surface water hydrology, 2) surface water and sediment quality; and 3) fish and fish habitat.

The long-term SWFM Plan includes a number of objectives to be achieved over the full extent of the program for Kearl (Imperial Oil 2009a), which extends past Kearl closure. The objectives of the 2018 monitoring program consisted of providing monitoring data that can be used in determining the effects of Kearl on surface water hydrology and water/sediment quality in the relevant portions of the Muskeg River and Firebag River watersheds within or downstream of the Kearl area, and in assessing the development of Muskeg Lake (Kearl Phase I Compensation Lake).

Hydrology Component

Hydrology monitoring has been conducted at Kearl since 2005, with the monitoring program incorporated into the long-term SWFM Plan starting in 2009. The 2018 hydrology monitoring program extended the streamflow record at previously-established streamflow monitoring stations in the Muskeg and Firebag River watersheds in and around the Kearl lease, and continued the collection of climate data initiated in 2009 at one location in the upper Muskeg River watershed. The hydrology program consists of manual stream discharge and water level measurements collected four times per year, and continuous (datalogger) water level and climate recordings. The data were analyzed, in combination with historical and regional data, to provide an integration with regional hydrometric monitoring data and provide comparisons to predictions from the Kearl Environmental Impact Assessment (EIA) (Imperial Oil 2005) that were made based on simulated flows using the Hydrological Simulation Program - Fortran (HSPF) model.

The Kearl surface water hydrology EIA focused on addressing changes in flows in the watercourses downstream of Kearl and changes in water balance of Kearl Lake. To evaluate the hydrology model predictions from the EIA, the predictions were compared with recorded monitoring data. The assessment indicated that the range of variability of flows and water levels recorded by Kearl and regional hydrometric stations were generally within the predicted flow and water level statistics provided in the Kearl EIA, with occasional exceptions.

For EIA predictions for Kearl Lake, the data indicates that the average annual lake levels up to 2005 were generally higher than they have been thereafter. This does not seem to be related to the filling of Muskeg Lake from 2010 to 2013 but is likely due to higher than average precipitation from 1999 to 2003 and in 2005 (as

measured at the regional climate monitoring station). For the Muskeg River downstream of Kearl, the mean ice-covered flows have been decreasing since 2012, although the mean open-water season flows and mean annual flows have been more stable. This watershed has increasing closed-circuit areas within it, and no overburden dewatering has occurred to date, which may explain why flows have not increased as originally predicted in the Kearl EIA. For the Muskeg River at the mouth, the seasonal open-water period and ice-covered period flows were predicted to increase for the year 2007. The EIA predictions were close to the average flows recorded by the regional monitoring station near the Muskeg River mouth.

Generally, the differences between the results of EIA model predictions and the monitoring data can be attributed to the difference in the assumptions used during the EIA assessment regarding the schedule of Kearl, Aurora South and Jackpine Phase 1 projects and the actual development schedules for these projects.

Water/Sediment Quality Component

In fall 2017 and during seasonal surveys in 2018, water and sediment quality samples were collected at watercourse stations in four watersheds downstream of the Kearl Project (Firebag River, Muskeg River, Muskeg Creek and Wapasu Creek) and in two waterbodies (Kearl Lake and Muskeg Lake). The data were analyzed, in combination with historical and regional data from 2006 to 2018, to evaluate changes in water and sediment chemistry over time.

Field and analytical water quality data for samples collected in fall 2017 and in 2018 at monitoring stations in the Kearl area were generally within typical ranges observed in the oil sands Region. The concentrations of water and sediment quality parameters were also generally consistent with the historical data collected at these monitoring stations in previous monitoring years. Concentrations of select polycyclic aromatic hydrocarbons (PAHs) in sediment data were occasionally above the range of historical data from previous monitoring years, likely due to eroded oil sands. Sediment toxicity test results generally indicate no adverse effect on survival of test organisms.

Muskeg Lake and Kearl Lake 2018 results indicated concentrations of metals in water quality samples and PAHs in sediment quality samples were generally higher in Muskeg Lake than Kearl Lake, and concentrations of metals in sediment samples were generally higher in Kearl Lake than Muskeg Lake. All other Muskeg Lake water and sediment quality analytical results were generally similar to Kearl Lake, or, in the case of total organic carbon in sediment, lower than Kearl Lake but expected to trend towards Kearl Lake concentrations over time.

Monitoring data collected to date was examined for possible trends in water and sediment quality in each of the four downstream watersheds. The number of guideline exceedances for most water and sediment quality parameters in all watersheds were similar in the Kearl baseline (pre-operational) phase compared to the operational phase; however, field pH was measured outside the chronic water quality guideline more frequently in the operational phase in all watersheds. There were no strong seasonal trends for total or dissolved metal concentrations in water samples; however, the fewest guideline exceedances were observed in summer. In general, more metal parameters in water samples exceeded guidelines in the Muskeg Creek watershed relative to other watersheds. Concentrations of hydrocarbons and PAHs in sediment samples in both the baseline and operational phases suggest that the sediment samples collected contained eroded oil sands.

Water quality parameters generally did not show temporal trends or showed only weak trends for the watercourse and lake monitoring stations. Most metal concentrations measured in the watercourse and lake stations were elevated at some point during construction and early operational phase but did not show any long-term trends. Total cobalt, dissolved iron, total and dissolved arsenic, and methyl mercury concentrations appear to have increased at some stations in the Muskeg River after the construction phase. Select parameters (i.e., sodium,

chloride, total Kjeldahl nitrogen, total aluminium, cobalt, iron, manganese and titanium concentrations) have increased in Muskeg Lake over time.

The monitoring data collected to date for Muskeg Lake were compared to the water quality model predictions for Phase I of Muskeg Lake presented in the Kearl No Net Loss Plan (NNLP) (Imperial Oil 2007) regarding expected trophic status, temperature profiles, dissolved oxygen profiles, and total dissolved solids concentrations over time. The model predictions were generally confirmed by the monitoring data collected to date. As expected, the characteristics of Muskeg Lake were similar to Kearl Lake conditions, except for parameters that were expected to be lower than Kearl Lake initially and trend towards Kearl Lake conditions over time.

Fish and Fish Habitat Component

As per the long-term SWFM Plan, the fish and fish habitat component of the 2018 monitoring program consisted of the following activities designed to collect fish habitat and fish population data for evaluating the biological development of Muskeg Lake, and data for assessing fish populations in Kearl Lake following 5 years of connection to Muskeg Lake.

- Collect habitat data in Muskeg Lake relative to assessing habitat development and lower-level productivity (i.e., key water quality parameters, macrophyte distribution, plankton sampling and benthic invertebrate sampling).
- Conduct a habitat-based fisheries inventory in Muskeg Lake to assess species colonization, composition, abundance and biomass.
- Conduct a fisheries inventory in Kearl Lake to assess species composition, abundance and biomass.

The 2018 monitoring results were integrated with the previous years results to track the trajectory of Muskeg Lake development over time and to provide an evaluation of the current level of biological development of the lake. Construction and filling of Muskeg Lake was completed by spring 2013 and the connector channel between Muskeg Lake and Kearl Lake was opened in 2014, allowing fish colonization of Muskeg Lake. The Muskeg Lake data summary includes plankton and benthic invertebrate data collected over the six-year period from 2013 to 2018 (lake filling to present) and five years of fish habitat and fish population data collected from 2014 to 2018 (start of fish colonization to present). In addition to evaluating the general biological development of Muskeg Lake, the monitoring data was compared to the specific predictions made for the lake as part of the lake design provided in the Kearl NNLP (Imperial Oil 2007).

Monitoring of fish populations in Kearl Lake was conducted in 2018 to provide data for comparison to previous data for the lake obtained during the five-year baseline sampling program that was conducted from 2009 to 2013, prior to Kearl Lake being connected to Muskeg Lake. Sampling was conducted in Kearl Lake in 2018 as it represents five years since the baseline program was completed. Fish inventory surveys were completed to evaluate if the connection to the secure overwintering habitats in Muskeg Lake has provided a benefit to the fish populations in Kearl Lake.

Muskeg Lake Biological Development

Physiochemical Characteristics

The hydrology assessment in the NNLP predicted that the combined Kearl-Muskeg lakes system would have stable water levels, with fluctuations typical for natural lakes in the region, facilitating development of a stable and productive littoral zone in Muskeg Lake. The evaluation of current water level data for the Kearl-Muskeg lakes system indicates that Muskeg Lake maximum water level fluctuations to date have been less than 0.6 m, matching the prediction that fluctuations over the long-term would be less than 1.0 m. Muskeg Lake has had a

stable water level since filling and data from the fish habitat surveys show the lake has developed stable and productive riparian and littoral zones, with an expanding riparian and aquatic vegetation.

Water quality data shows that, based on nutrient levels, Muskeg Lake has transitioned from oligotrophic to mesotrophic status over the development period to date and currently has a trophic status similar to Kearl Lake. This matches the NLLP prediction for the early stages of the lake, with the lake expected to trend towards meso-eutrophic status in the future.

Assessment of the continual temperature recordings from the datasondes deployed during the open water periods from 2014 to 2018 show average summer temperatures to be 19.1ºC, the range of maximum weekly summer temperatures to be 22.4°C to 23.2°C, and the maximum peak temperatures to be 22.9°C to 25.2°C. These measurements confirm the NNLP model prediction of an average summer temperature of 19°C and are similar to the predicted maximum summer temperature of 24.5°C.

The NNLP does not provide specific predictions for pH in Muskeg Lake but assumes the pH range will be the same as Kearl Lake, with the pH range of 6 to 9 used as the input for fish Habitat Suitability Index (HSI) modelling. The datasonde records for Muskeg Lake show a pH range of 7.5 to 9.1 for all monitoring years combined, matching the inputs used for NNLP fish habitat modelling.

Measured dissolved oxygen levels show a greater degree of variability than predicted in the NNLP. Open-water dissolved oxygen levels were both higher and lower at times than the predicted primary range of 7.2 to 8.2 mg/L, and were higher at times than the overall range of 5 to 9.5 mg/L. In the winter, the under-ice depth to which dissolved oxygen levels of 5 mg/L or higher were maintained was sometime less than predicted, while dissolved oxygen levels at the lake bottom were sometimes higher than predicted. In all years, Muskeg Lake, including the majority of lake depths in the winter, provided dissolved oxygen levels highly suitable as secure overwintering habitat for the target fish community of forage fish, Norther Pike, Yellow Perch and White Sucker.

TDS concentrations in Muskeg Lake after filling were in the range of 150 to 250 mg/L, most recently stabilizing at approximately 200 mg/L. The current TDS levels in Muskeg Lake are somewhat lower than the predicted range of approximately 230 to 245 mg/L for the Phase I lake but are within the range of values for Kearl Lake, as predicted. All TDS values measured in Muskeg Lake are in the optimal range for the fish species for which TDS is a factor in determining habitat suitability.

Predictions for mercury levels in Muskeg Lake were not included in the NNLP; however, mercury concentrations were evaluated due to the concern with potential increases in mercury in fish tissue that have been documented to occur in some constructed and flooded waterbodies. The 2012 to 2018 water quality monitoring data shows that total mercury levels in Muskeg Lake water were similar to, and slightly lower than, Kearl Lake, while methyl mercury was below detection limits in both lakes and total mercury in Muskeg Lake sediment was also below detection limits. The monitoring data demonstrates that there has been no increase in mercury or bio-available mercury in Muskeg Lake due to flooding of the basin. This is likely due to the fact that the lake was created by excavation, removing vegetation and organic soil prior to flooding, a key mitigation measure to prevent mercury increases.

Biological Components

Aquatic macrophyte stands were planted in the littoral zone of Muskeg Lake in August 2013, consisting of Richardson's Pondweed (*Potamogeton richardsonii*) propagules and Softstem Bulrush (*Schoenoplectus tabernaemontani*) propagules. In addition to the macrophyte plantings, natural colonization of the Muskeg Lake littoral zone has occurred for other emergent and submergent vegetation species. Mapping of aquatic vegetation

in Muskeg Lake from 2016 to 2018 indicates continuing colonization and expansion of aquatic macrophytes in the lake. Macrophyte development has not yet achieved the average littoral density of 57% predicted in the NNLP but expansion of macrophyte distribution and density in Muskeg Lake is expected to continue through both new colonization and expansion of existing stands.

Zooplankton and phytoplankton samples were collected in Muskeg Lake annually from 2013 to 2016. The results indicate that zooplankton development in Muskeg Lake took two years (richness) to four years (biomass) to reach levels comparable to Kearl Lake. From four to six years after filling (2016 to 2018), zooplankton biomass and richness levels have been comparable to, or higher than, Kearl Lake. In comparison, the results indicate that phytoplankton development in Muskeg Lake was rapid, occurring during the lake filling phase from 2010 to 2013. For five of the six post-fill monitoring years (2013 to 2016 and 2018), phytoplankton biomass has been similar to the lower range observed in Kearl Lake, while 2017 levels exceeded the maximum Kearl Lake level.

The 2013 to 2018 benthic invertebrate monitoring results indicate that Muskeg Lake benthic invertebrate colonization began during the Muskeg Lake filling phase, followed by rapid colonization and development of the benthic invertebrate community in the littoral zone and slower development in the pelagic zone. In comparison to Kearl Lake, littoral benthic invertebrate density and richness levels in Muskeg Lake were similar to or exceeded levels typical of the natural lake within two years of filling, providing a strong food base for fish. This matches the general prediction provided in the NNLP that it would require one to five years to achieve levels comparable to natural environments. Comparison to other regional lakes indicated benthic invertebrate densities within the post-colonization phase of Muskeg Lake were comparable to some neighboring regional lakes but were lower than the larger regional lakes.

The development of fish populations in Muskeg Lake has occurred fairly rapidly over the first five years since the lake connector channel was opened to allow fish colonization from Kearl Lake. Fish species diversity is high in Muskeg Lake, with all fish species currently or historically documented to be present in Kearl Lake now also present in Muskeg Lake, providing the maximum species diversity that is achievable through colonization. This includes all six of the seven fish species targeted for inclusion in the Muskeg Lake community in the NNLP that are present in the Kearl Lake/Muskeg Creek drainage area. The seventh fish species targeted for the fish community in the NNLP (Yellow Perch) is not present in Kearl Lake or in the drainage basin. As identified in the NNLP, Yellow Perch would require stocking to become part of the Muskeg Lake fish community.

Fish abundance (as represented by catch-per-unit-effort [CPUE]) and biomass (as represented by biomass-per-unit-effort [BPUE]) have developed well in Muskeg Lake. Forage fish populations developed rapidly, achieving CPUE and BPUE levels comparable to Kearl Lake the year of connector channel opening and the following year, respectively. Forage fish CPUE levels in Muskeg Lake are also comparable to other regional natural or mature, man-made waterbodies. Large-bodied fish populations developed more slowly than did forage fish, which was expected based on the low abundance of suckers and general absence of Northern Pike in Kearl Lake due to the lake's lack of pelagic habitat. Nonetheless, the abundance and biomass levels of the Muskeg Lake large-bodied fish community exceeded those of Kearl Lake within three years of connector channel opening. Currently, Muskeg Lake supports a large-bodied fish community, and in particular Northern Pike and White Sucker populations, with CPUE levels comparable to natural regional lakes that also provide deep-water pelagic habitats.

Fish Habitat Suitability Index Modelling

Fish Habitat Suitability Index (HSI) models have been developed for the Alberta oil sands region (Golder 2008) to assist with determination of habitat quality for natural habitats and for habitats constructed to compensate for alterations of natural habitats. HSI values are used in conjunction with measures of habitat quantity (i.e., surface area) to provide a quantification of the estimated habitat productivity in the relevant habitats. Habitat productivity is

represented by Habitat Units, calculated as: HUs = HSI x surface area (m^2). The Kearl NNLP (Imperial Oil 2007) provided HSI and HU calculations for all affected habitats and for the compensation habitats to be developed in Muskeg Lake. To provide the specified amount of compensation for the affected HUs, Muskeg Lake is designed to provide a specific amount of HUs for the fish species expected to form the fish community. To quantify the trajectory and current estimated productivity level of Muskeg Lake, calculations were completed for the HSI values and HUs provided to date in relation to the modelled predictions in the NNLP.

To show the trajectory of habitat development and the current maturity level of Muskeg Lake, HSI and HUs were calculated for the last three years of monitoring data (2016, 2017 and 2018). The Muskeg Lake values were then compared to the modelled HSI values and HUs from the NNLP to gauge the degree to which the lake matches the predictions and to identify the specific habitat components that need further developmental time.

The HSI models each consist of a number of habitat variables, representing the physiochemical and biological characteristics of the lake, with defined ranges of suitability used to assign the Suitability Index (SI) for the variable. As specified by the requirements of the various HSI models, SI modelling input data was provided by the Muskeg Lake as-built specifications (surface area, bathymetry) and the hydrology (water level), water quality (dissolved oxygen, temperature, pH, TDS) and fish habitat (macrophytes, datasonde) monitoring results.

The HSI values were calculated individually for each of the seven species identified in the NNLP for the Muskeg Lake fish community, as well as the three additional species that have colonized Muskeg Lake. The HSI values were calculated for each individual species for each of the three recent years of monitoring data (2016, 2016 and 2018) to show how the lake has developed over time.

The estimated productivity of Muskeg Lake, as represented by the total number of HUs, increased from 759,104 in 2016 to 1,093,112 in 2018 for the seven fish species identified in the NNLP. As of 2018, Muskeg Lake is estimated to provide 89% of the 1,230,000 HUs the lake is expected to provide at maturity for these species. Additional HUs were also calculated to be present in Muskeg Lake for the three additional species that have colonized the lake.

The HSI values for six of the seven species identified for the Muskeg lake fish community have shown an increase over the three-year assessment period (2016 to 2018), while the HSI values for one species (White Sucker) had already met the NNLP modelled expectation in 2016. The HSI values for all four of the target forage fish species (Brook Stickleback, Fathead Minnow, Lake Chub and Pearl Dace) reached the NNLP modelled expectations by 2017 or 2018, depending on the species. Although Northern Pike HSI increased over time from 0.16 to 0.40, the 2018 value has not yet achieved the NNLP modelled expectation of 0.50. The HSI value for Northern Pike is currently limited by the level of aquatic vegetation development in the lake and is therefore expected to reach the modelled prediction given further developmental time. The HSI value for Yellow perch (0.30), a species not present in Muskeg Lake but considered for future stocking, is lower than the NNLP modelling prediction of 0.70. Habitat suitability for Yellow Perch is currently limited by spring water temperatures appearing to be too warm. However, water temperatures have only been monitored in Muskeg Lake in the late spring. Therefore, advancing the installation of the water quality datasondes to occur immediately after ice-out in the spring is recommended for future monitoring. It is expected that obtaining temperature records for the entire spring period would show a higher suitability for this species.

Kearl Lake Fish Populations

In the first survey conducted for Kearl Lake since the opening of the connector channel to Muskeg Lake, the results show the abundance (CPUE) and biomass (BPUE) for small-bodied forage fish was within the range found during baseline conditions (2009 to 2013), while results for large-bodied fish species showed a large increase from baseline conditions. Large-bodied fish BPUE has seen a 10-fold increase over what was observed during baseline conditions. This was mainly due to the presence of Northern Pike in Kearl Lake, as Northern Pike was not found in the lake during baseline sampling. As a benefit of Muskeg Lake construction, it was intended that Northern Pike would be able to establish a permanent population in Kearl Lake as a result of the connection to Muskeg Lake and its secure overwintering habitat.

1.0 INTRODUCTION

Imperial Oil Resources Limited (Imperial) is in the process of operating the initial stages of the Kearl Oil Sands development (Kearl). As part of Kearl, Imperial has prepared a long-term monitoring plan to be implemented throughout the life of Kearl. The long-term monitoring plan, termed the Surface Water and Fish Monitoring (SWFM) Plan (Imperial Oil 2009a), is designed to meet the monitoring conditions specified for Kearl by federal and provincial regulatory agencies and is based on the conditions specified in the Authorization provided by Fisheries and Oceans Canada (DFO) pursuant to Section 35(2) of the *Fisheries Act* (Authorization No. ED-03-2806 – June 2, 2008), as well as the Alberta *Environmental Protection and Enhancement Act* (EPEA) Approval (Approval No. 46586-00-00 – November 9, 2007, as amended). The SWFM Plan addresses monitoring requirements of both the Fisheries Act Authorization and portions of the EPEA Approval that relate to the Kearl habitat compensation plan and to hydrology/climate monitoring. Details of the habitat compensation plan are provided in the Kearl Oil Sands Project – Mine Development: No Net Loss Plan (NNLP) (Imperial Oil 2007).

The long-term SWFM Plan was designed to:

- monitor for potential effects of Kearl on the aquatic environment within and adjacent to the Kearl area; and
- evaluate the effectiveness of fish habitats constructed to provide compensation for habitats affected by Kearl development.

The long-term monitoring plan includes monitoring of three environmental components:

- surface water hydrology;
- surface water and sediment quality; and
- fish and fish habitat.

The long-term SWFM Plan was implemented in 2009 with the start of the monitoring activities specified in the plan, and has continued on a yearly-basis with annual reports as follows:

- 2009 – Year 1 (Imperial Oil 2009b)
- 2010 – Year 2 (Golder 2010a)
- 2011 – Year 3 (Golder 2011)
- 2012 – Year 4 (Golder 2012)
- 2013 – Year 5 (Golder 2013a)
- 2014 – Year 6 (Golder 2014)
- 2015 – Year 7 (Golder 2015)
- 2016 – Year 8 (Golder 2017a)
- 2017 – Year 9 (Golder 2017b)

This document provides a description of monitoring activities conducted in 2018 (Year 10) and how these activities relate to the long-term monitoring plan. This document presents the data that was collected during 2018 monitoring activities, as well as analytical results for samples collected in 2017 for which laboratory analysis was not available at the time of preparation of the previous monitoring report. This document also provides a summary of previous monitoring results in relation to the monitoring objectives, which is conducted every five years of the monitoring program, as described below.

The long-term monitoring plan includes monitoring locations established and monitored by Imperial, as well as consideration of monitoring results at monitoring locations established for regional monitoring programs that are part of the integration between Kearl monitoring and regional initiatives. Regional monitoring activities and results are provided by Regional Aquatics Monitoring (RAM), which consists of aquatic monitoring in the oil sands region conducted and reported by the:

- Regional Aquatics Monitoring Program (RAMP) from 1997 to 2012;
- Joint Oil Sands Monitoring (JOSM) Plan from 2013 to 2015 – supported by the RAMP Steering Committee in 2013 and by the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA) in 2014/2015; and
- Oil Sands Environmental Monitoring (OSM) Program, jointly managed by Alberta Environment and Parks (AEP) and Environment and Climate Change Canada (ECCC) from 2016 onward.

The 2018 Kearl Monitoring data presented in this document includes the monitoring data collected at Imperial monitoring locations as well as regional (RAM) water quality monitoring stations for which Imperial supplemented monitoring activities in 2018. The supplementation of regional water quality monitoring stations by Imperial increased for the 2014 through 2018 programs relative to previous monitoring years due to the reduction in sampling effort by the regional monitoring agencies.

Multi-year summary of Kearl monitoring results and incorporation of available RAM monitoring results in the analyses of Kearl monitoring data occurs at specified intervals (i.e., every five years). The first of the five-year summary analyses was completed in 2013 (Year 5; Golder 2013a). This report (2018 monitoring year) represent Year 10; therefore, this report provides the second five-year summary of the monitoring results.

Due to the previous report submission timeline (i.e., end of December of the monitoring year), laboratory analytical results for some samples collected in late summer or fall 2017 (i.e., water quality, sediment quality/toxicity, plankton and benthic invertebrates) were not available at the time of preparation of the 2017 Annual Monitoring Report and are presented in this (2018) monitoring report. With revision in 2018 of the report submission timeline to end of March of the year following monitoring, data for samples collected in late summer or fall of the current monitoring year (2018) are presented in this report. For subsequent monitoring years, all data are expected to be available at the time of preparation of the relevant annual report.

2.0 OBJECTIVES

The long-term SWFM Plan includes a number of objectives to be achieved over the full extent of the program for Kearl (Imperial Oil 2009a), which extends past Kearl closure (currently scheduled for 2065). The main objective that is relevant to the 2018 monitoring program is continuing monitoring activities associated with the early stages of Kearl. For 2018, this objective consisted of providing monitoring data that can be used in determining the effects of Kearl on surface water hydrology and water/sediment quality in the relevant portions of the Muskeg River and Firebag River watersheds within or downstream of the Kearl area, and in assessing the development of Muskeg Lake (Kearl Phase I Compensation Lake).

As per the long-term SWFM Plan, the 2018 monitoring program included monitoring of three environmental components: 1) hydrology, 2) water/sediment quality, and 3) fish and fish habitat. Monitoring locations (i.e., stations) surveyed in 2018 for each of the three components are presented in Figure 2-1. Monitoring stations for the hydrology and water/sediment quality components in 2018 were generally the same as the stations used for previous data gathered by Imperial at various times over the period 2005 to 2017, with stations surveyed prior to the SWFM Plan being rolled into the Plan in 2009. In contrast, the fish and fish habitat component monitoring stations for 2016 through 2108 were reduced compared to the previous monitoring years (i.e., 2009 to 2015). This is consistent with the schedule presented in the long-term SWFM Plan (Imperial Oil 2009a), as the focus of the fish and fish habitat component moved from collecting additional baseline data within and downstream of the Kearl area to collecting monitoring data for Muskeg Lake. Fish and fish habitat monitoring in 2009 and 2010 focused on a number of monitoring stations in affected habitats to collect data for Habitat Suitability Index (HSI) model validation, as well as monitoring in Kearl Lake. In 2011, monitoring of affected habitats was discontinued, as planned, and the number of stations was reduced to locations in the Muskeg River and Wapasu Creek downstream of the Kearl area, with continued monitoring in Kearl Lake. Initial monitoring in Kearl Lake was completed in 2013 and initial monitoring in the Muskeg River and Wapasu Creek downstream of the Kearl area was completed in 2015, after five consecutive years of monitoring in both cases.

Construction of Muskeg Lake was completed in 2010 and filling of the lake basin with water from Kearl Lake was completed in spring 2013. The connector channel between Muskeg Lake and Kearl Lake was opened in 2014, allowing colonization by fish species. Monitoring of Muskeg Lake water quality began during lake filling in 2012 and continued to 2018, with the addition of sediment quality monitoring from 2013 to 2018. Monitoring activities described in the long-term monitoring plan related to initial monitoring of the biological development of Muskeg Lake began in 2013 and continued through 2018.

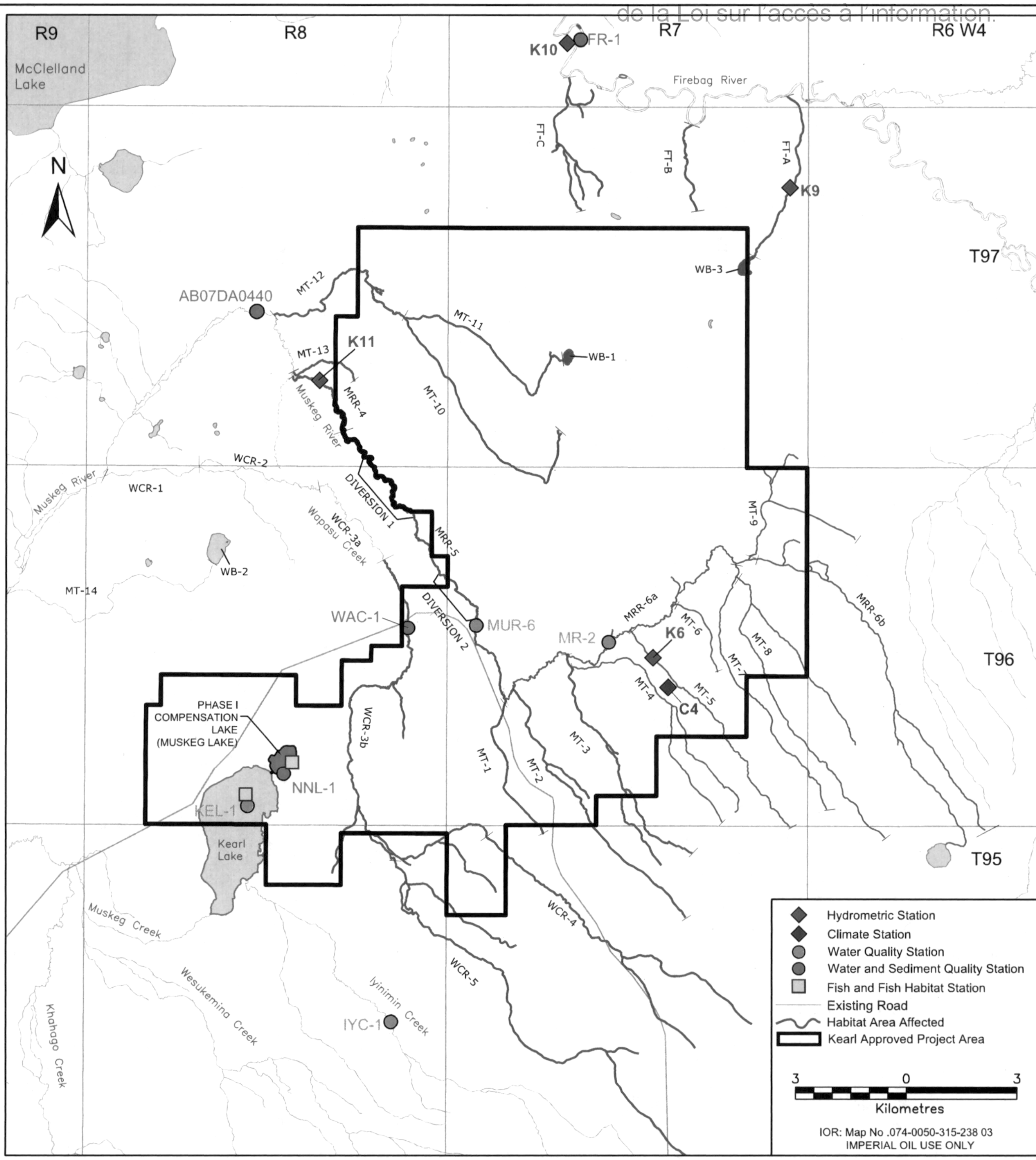
Following collection of five years of baseline data for Kearl Lake (i.e., 2009 to 2013), the SWFM Plan includes subsequent monitoring of Kearl Lake at regular intervals (currently every five years). Therefore, the 2018 fish and fish habitat program also included monitoring of fish populations in Kearl Lake. The objective of this monitoring was to assess potential benefits to Kearl Lake associated with connection to Muskeg Lake and the possibility that overwintering habitats in the deeper Muskeg Lake provide support to Kearl Lake fish populations and productivity.

One goal of the 2018 monitoring program was to complete the 2018 component of the long-term SWFM Plan (Imperial Oil 2009a), consisting of the collection of aquatic monitoring data to provide information for comparison to future monitoring data. This included the collection of aquatic data for each of the three environmental components, as described in the following sections.

074-0050-315-238 03

AutoCAD

CADD DRAWING NO MANUAL CHANGES



Version: 3

A-PSTD

NOTES:

Imperial

IMPERIAL OIL RESOURCES

KEARL - MINING
2018 MONITORING STATIONS
AQUATICS SITE LOCATIONS MAP

PROJECTION	DATUM	CONTRACTOR NAME	CONTRACTOR DRAWING NUMBER
UTM 12N	NAD83	GOLDER ASSOCIATES LTD.	FIGURE 2-1

DRAWN	CHECK	DESIGN	APPR.	DATE	SCALE	MAP NUMBER	REV
RFM	AT			19 03 25	1:150,000	074-0050-315-238 03	A

Filename: L:\IMPERIAL_OIL\KEARLMINING\1788087\02_PRODUCTION\109\DWG\1788087_109-HS-0001 MONITORING STATIONS.DWG User ID: BMCDONALD Plot date/time: March 25, 2019 - 9:12am

2.1 Hydrology Program

The objectives of the hydrology component of the 2018 monitoring program were to:

- collect additional hydrometric and climate monitoring data in the vicinity of the Kearl area through the continuation of monitoring activities completed up to 2018 for representative watercourses;
- provide the results, observations and challenges for the 2018 monitoring program: and
- provide a synthesis and integration with regional hydrometric monitoring data as part of the five-year summary, as specified in the SWFM Plan;
  - present and discuss the available hydrology and climate station datasets, from monitoring program inception to present, for both Kearl and regional monitoring stations; and
  - Present comparisons of Kearl and regional monitoring data to predictions from the Kearl Environmental Impact Assessment (EIA) (Imperial Oil 2005).

2.2 Water and Sediment Quality Program

The objectives of the water and sediment quality component of the 2018 monitoring program were to:

- collect additional monitoring data in the vicinity of the Kearl area through the continuation of monitoring activities completed from 2006 to 2017 for representative watercourses and waterbodies;
- continue the collection of monitoring data in the Muskeg River downstream of the Kearl area, which was previously conducted from 2009 to 2017;
- continue the collection of water and sediment quality data to monitor development of Muskeg Lake; sampling was initiated in 2012 during the lake filling period for water quality and in 2013 once lake filling was complete for sediment quality;
- provide the water quality, sediment quality and sediment toxicity data for samples collected from fall 2017 to fall 2018;
- provide a summary of Kearl monitoring data collected from 2006 to 2018, integrated with regional monitoring data (e.g., RAM and AEP) collected at relevant monitoring stations in the Muskeg River basin, as specified in the SWFM Plan;
  - compare compiled data to water and sediment guidelines currently used in Alberta (GOA 2018; HC 2017; CCME 1998);
  - evaluate temporal trends for the compiled water quality data; and
  - compare Muskeg Lake water quality data to the predictions outlined in the Kearl NNLP (Imperial Oil 2007).

2.3 Fish and Fish Habitat Program

The objectives of the fish and fish habitat component of the 2018 monitoring program were to:

- continue monitoring the biological development of Muskeg Lake that was initiated upon lake filling in 2013;
- provide the analytical benthic invertebrate and plankton data for Muskeg Lake samples collected in 2017 that were not available for the 2017 annual report;
- provide the results of the 2018 monitoring program;
- provide the summary of the development of the biological components of Muskeg Lake over its first five years of development (i.e., since opened to fish colonization in 2014); and
- provide a comparison of current biological development of Muskeg Lake to Kearl Lake and other regional waterbodies, and to the predictions in the NNLP (Imperial Oil 2007).

The 2018 fish and fish habitat monitoring program is a continuation of monitoring the initial biological development of Muskeg Lake, as identified in the long-term SWFM Plan. Monitoring of biological development began at lake filling in 2013 with lower-trophic levels (i.e., plankton and benthic invertebrates), while fish habitat and fish population monitoring was initiated with opening of the connector channel from Kearl Lake in 2014. Therefore, data available for the summary includes six years of lower-trophic data (2013 to 2018) and five years of fish and fish habitat data (2014 to 2018).

The fish and fish habitat monitoring component is comprised of several sub-components, but the current five-year summary is limited to Muskeg Lake monitoring data. Summaries of the previous monitoring activities for the other sub-components have been provided at appropriate times during the monitoring program as follows:

- a summary of the 2009 to 2010 sub-component to collect additional site-wide baseline data and initial HSI model validation data was provided in the 2011 Annual Monitoring Report (Golder 2011);
- a summary of the 2009 to 2013 sub-component to collect five years of baseline data for Kearl Lake was provided in the 2013 Annual Monitoring Report (Golder 2013); and
- a summary of the 2011 to 2015 sub-component to collect baseline data for downstream watercourses (i.e., Muskeg River and Wapasu Creek) was provided in the 2015 Annual Monitoring Report (Golder 2015).

3.0 HYDROLOGY PROGRAM

3.1 Hydrology Monitoring Program Overview

Hydrology monitoring has been conducted at Kearl since 2005, with the monitoring program incorporated into the long-term SWFM Plan starting in 2009. There have been several changes since inception, with the current program consisting of four hydrometric (stream flow) monitoring stations and one climate monitoring station located in and around the Kearl lease (Figure 2-1). In addition to the Kearl program climate and hydrometric stations, there are several regional hydrometric stations in the Muskeg River and Firebag River watersheds which were installed and operated by either the Water Survey of Canada (e.g., Firebag River at the Mouth [07DC001] and Muskeg River at the Mouth [07DA008]), or by RAM (e.g., Muskeg River above Stanley Creek [S5]). The regional hydrometric stations are discussed in Section 3.5 as part of the assessment of regional trends and Kearl EIA predictions.

The 2018 hydrology monitoring program extended the streamflow record at previously-established streamflow monitoring stations in the Muskeg and Firebag River watersheds in and around the Kearl lease and continued the collection of climate data at one location in the upper Muskeg River watershed. The hydrology program consists of manual stream discharge and water level measurements collected four times per year, and continuous (datalogger) water level recordings.

Two monitoring stations were moved during the 2018 field programs to new locations that are currently free of obstruction and backwater by beaver activity, which has been prolific in most of the small streams in the area. A summary of currently operating station locations and details is provided in Table 3-1, and station locations are shown in Figure 2-1. All hydrology stations now operate year-round but require seasonal calibration and maintenance.

Four seasonal field visits were completed in 2018: winter (8 to 10 March), spring (14 to 17 May), summer (22 to 24 August and 5 September) and fall (15 to 18 October). Details of the fields visits to each monitoring station are provided in Section 3.2. As in recent survey years, Station K10 on the Firebag River was inaccessible by Argo and was visited during all events by helicopter. Station K9 (Firebag River tributary) was visited by helicopter during the winter event and was dismantled due to ground access issues along with excessive beaver activity – the station was re-installed during the spring event at a more accessible location unaffected by beavers. Station K6 (Muskeg River tributary) was moved during the spring event due to a large beaver dam creating overland flow around the station. Water levels and discharges were measured at each site during all other field visits. Data from all hydrometric dataloggers (Constant Flow Bubbler [CFB] units) were downloaded during each field visit.

Table 3-1: Kearl Hydrology and Climate Monitoring Station Details

Station ID	Station Name	Watershed Area (km^2)	Watercourse	UTM Coordinates	Period of Record [(a)]	Parameters Monitored
Operating Stations						
K6	Muskeg River Upland Tributary	11.6	Muskeg River Tributary MT-5	496930 E, 6354618 N	2005-2013 (seasonal) 2014 to 2018 (year-round)	Water level and discharge
K9	Firebag River Tributary	15.8	Firebag River Tributary FT-A	500620 E, 6367343 N	2005-2013 (seasonal) 2014 to 2018 (year-round)	Water level and discharge
K10	Firebag River	3,410	Firebag River Downstream of Kearl	494947 E, 6371299 N	2005-2013 (seasonal) 2014 to 2018 (year-round)	Water level and discharge
K11	Muskeg River Lowland	182	Muskeg River in Segment MRR-4	487039 E, 6362935 N	2007-2013 (seasonal) 2014 to 2018 (year-round)	Water level and discharge
C4	Muskeg River Watershed Climate Station	n/a	Adjacent to Muskeg River Tributary MT-5	497087 E, 6354492 N	2011-2018 (seasonal)	Air temperature, atmospheric pressure, rainfall
Discontinued Stations						
K7	Muskeg River Upland Tributary	Watercourse Removed by Kearl Development	Muskeg River Tributary MT-12	Watercourse Removed by Kearl Development	2005-2010 (seasonal)	Water level and discharge
C3	Muskeg River Watershed Rain Gauge	n/a	n/a	497521 E, 6353768 N	2009-2010 (seasonal)	Rainfall

[(a)] Period of record indicated does not include data gaps due to sensor malfunction. Seasonal refers to stations that usually collected data from mid-May to mid-October.

Note: UTM = Universal Transverse Mercator Grid Coordinates, North American Datum (NAD) 1983, Zone 12; E = easting; N = northing; n/a = not applicable.

3.2 Monitoring Methods

3.2.1 Hydrometric Monitoring

Prior to 2014, water level sensors were in place at the hydrometric stations during the open-water period and were removed for the winter. Permanent and more robust hydrometric stations were installed at all four hydrometric monitoring sites in 2014. The permanent stations remain in place year-round and consist of the following components:

- Sutron Constant Flow Bubbler (CFB);
- Golderwatch telemetry unit;
- protective steel case;
- solar panel and regulator;
- orifice line;

- local benchmarks; and
- markers at each edge of the discharge cross-section.

The type of CFB unit installed at the monitoring stations is also used by the Water Survey of Canada (WSC) and includes a small compressor that operates the CFB unit. The CFB unit works by forcing bubbles down an orifice line anchored on the stream bottom and into the stream. By comparing atmospheric pressure and the pressure required to force a bubble through the orifice tube, the water pressure at the tube outlet (and hence the water depth) can be calculated by the unit.

The Golderwatch telemetry unit broadcasts the station data via satellite to a secure server. Data are accessed via a secure website and can be viewed or downloaded as required. Alarms are setup to alert the operator of potential problems.

The benefits of the CFB gauge system are as follows:

- the stations are more robust, and can be left in-place year-round (i.e., can survive ice conditions);
- because the stations operate year-round, spring freshet can be captured without having to mobilize a crew and risk re-installation of the stations during unsafe conditions; and
- telemetry allows real-time information to mobilize staff to resolve malfunctioning station issues or to conduct manual measurements at required flow levels (i.e., to "fill out" the rating curve).

A typical CFB gauge datalogger station configuration is shown in Figure 3-1. Since 2017, water level pressure transducers (i.e., HOBO brand loggers) have also been installed each spring for the open-water season to act as a back-up for each of the CFBs.

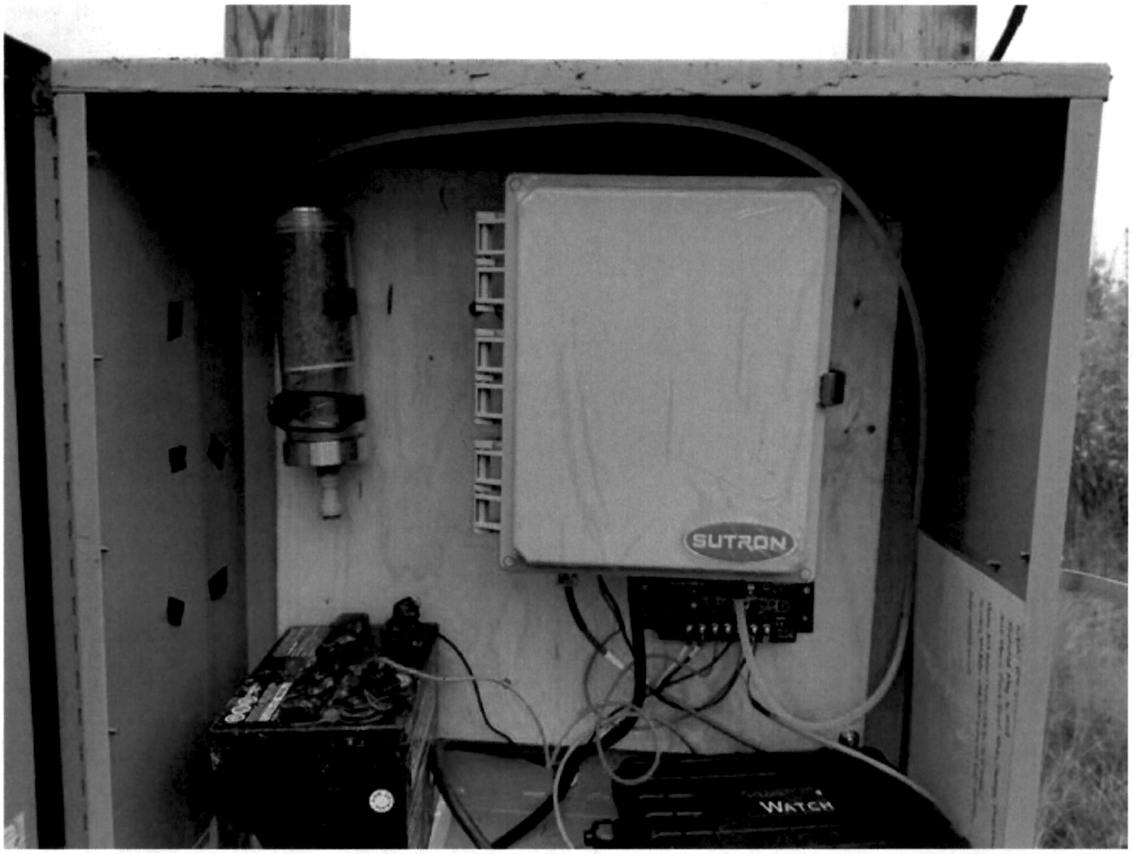


Figure 3-1: Typical Hydrometric Station Datalogger Configuration for a Constant Flow Bubbler

3.2.1.1 Field Data Collection

An electronic field form was used to collect the required hydrology field data to provide a checklist of tasks to complete at each station. This tablet-based form (developed using Formotus software) provides data validation and error checking in the field and is subsequently downloaded to the server.

Manual flow and water level measurements were taken at each hydrometric monitoring station during each seasonal site visit where site conditions permitted and it was safe for field staff (e.g., measurements during high floods were not always possible). Water levels were surveyed at each station in relation to temporary benchmarks established at each location. For flow measurements, a Sontek Flow Tracker Acoustic Doppler Velocimeter (ADV) was used for shallow streams and a Sontek RiverSurveyor M9 Acoustic Doppler Profiler (ADP) was used for deeper streams that were unsafe to wade. At each station, a cross-section free of debris was chosen for the manual discharge measurements. The manual measurements were used to establish and update the stage-discharge rating curves. Rating curves were subsequently used to transform continuously recorded water level measurements into continuous flow estimates.

Quality assurance (QA) and quality control (QC) procedures implemented for the hydrology monitoring program include the following:

- developing and following specific work instructions for each field visit that include specific tasks and activities;

- checking real-time water level and datalogger records using the telemetry system to verify if stations were operating properly prior to field visits, or if maintenance was required;
- testing instruments to verify that they are in working order before field trips;
- running QA tests on current meters that are specific to each type of meter;
- downloading recorded data during each field visit to reduce the risk of complete data loss due to instrument malfunction or damage to the monitoring station;
- keeping detailed field notes (using electronic forms or hard copy field books) documenting site conditions that may affect the quality of data collected, and equipment issues or changes to settings on the CFB gauge dataloggers;
- verifying that water level and flow measurements compare to the stage-discharge curve prior to accepting the values and leaving the sites;
- verifying that stations are running properly before leaving the sites; and
- checking for errors or missing data in recorded data as it was downloaded.

3.2.2 Climate Monitoring

The current climate station C4 consists of a battery-powered HOBO Onset data logging system with two connected sensors: a 0.2 mm tipping bucket rain gauge (TBRG) and an air temperature sensor. The TBRG provides information on both total rainfall and rainfall intensity. A separate volumetric rainfall gauge was installed to validate TBRG observations. Station C4 was originally installed in May 2011 beside the K6 hydrometric station. Prior to 2011, only rainfall data was collected at the Muskeg River watershed climate station (Station C3). Station C3 was destroyed by animals twice (in spring 2009 and fall 2010) and was consequently relocated and upgraded to Station C4.



Figure 3-2: Climate Monitoring Station (C4)

3.2.3 Data Processing and Storage

Water level data retrieved from the CFB dataloggers were corrected to remove any potentially erroneous data and adjusted for minor sensor drift. If a sensor drift of more than 5 mm occurred (i.e., if there was a difference between the manually measured water level and the logger level), the recorded hourly interval water level data was corrected using the water levels manually measured during the site visit. It was assumed that sensor drift was linear, and thus the sensor drift correction factor for each data logger measurement was calculated using the difference between the data logger and the manually measured water level divided by the length of time between the current and previous manual water level measurements. Water level data was corrected using the AQUARIUS[1] time series software package. Stage-discharge points from 2018 were used to update the existing rating curve for each station using AQUARIUS. Stage-shifts were applied to the field measurements where necessary for each station to account for observed backwater due to vegetation growth in the channel (e.g., at Station K9 before it was moved farther upstream), downstream beaver activity or channel ice (e.g. at Station K10 in fall 2018).

[1] AQUARIUS is also used by Environment Canada and the United States Geological Survey (USGS) to manage data from their hydrologic station networks.

3.3 2018 Hydrology Monitoring Results

3.3.1 2018 Monitoring Station Overview

A summary of 2018 flow monitoring data quality for the four hydrometric monitoring stations is provided in Table 3-2. A summary of the status and field observations for the hydrometric stations and climate station in 2018 are provided in the sub-sections below. Daily mean flows for each station are provided in Appendix I, and rating curves are shown in Appendix II.

Table 3-2: Summary of 2018 Hydrometric and Climate Station Data Quality

Station	Quality of Rating Curve / Water Level Data	Field Observations
K6 – Muskeg River Tributary MT-5	Poor / Good	Due to beaver activity both upstream and downstream of this station, it was moved in August to a new location. Discharge records for the preceding period were corrected using field measurements. Discharge was estimated for the new station location using a preliminary rating curve extrapolated to higher and lower flows and water levels.
K9 – Firebag River Tributary FT-A	Poor / Missing Data	Due to continued backwater at this station, it was dismantled in March 2018 and reinstalled in May 2018 at a new location 2.6 km upstream of the previous one.
K10 – Firebag River Downstream of Kearl	Excellent / Missing Data	The rating curve at this station is well-established and stable, however all the 2018 data were adjusted to the existing rating curve by the same stage correction factor used in 2017, when the benchmarks were lost (the trees with the benchmark nails at the station fell due to wind). Spring flows were usually quite high and had to be measured with an ADCP - future crossings of the river should be made using motorized boat(s).
K11 – Muskeg River in Segment MRR-4	Good / Good	Beaver activity causing flooding and backwater near the station is considered to somewhat reduce the accuracy of the discharge results estimated using the existing rating curve. The station is, however, considered to be in the best possible location that best balances all factors, including access and beaver activity. The 2018 discharge records were corrected in Aquarius using stage-shifts from the established rating curve and a complete flow record is available for 2018.
C4 - Climate Station - Muskeg River Watershed	Not Applicable	The air temperature sensor malfunctioned starting on 5 May 2018, but this was not noticed until later in the year, and the volumetric graduated rain gauge installed in May was damaged by wildlife. The tipping bucket rain gauge remained operational at the station in 2018, although data could not be downloaded due to communication issues in October 2018, therefore rainfall records are currently only available until 23 August 2018.

3.3.1.1 Station K6 –Muskeg River Tributary

Monitoring of Muskeg River upland tributary MT-5 (Station K6) has historically been challenging. Station K6 was moved approximately 1.3 km downstream of its original (2005 to 2010) location in 2011. Beaver activity in 2013 required that the station be moved again in spring 2014. A beaver dam was observed 10 m upstream of the station during the 2016 spring field visit, and beaver dams were present both upstream and downstream of the station during all 2017 field visits, resulting in backwater at the station. During both the 2017 (winter, spring, and fall) and 2018 (spring and summer) visits the upstream beaver dam was overflowing and there was overland flow around the station. Additional discharge measurements were attempted along a secondary channel caused by the overland flow, but due to the minimal flow and presence of vegetation, the data was not considered reliable and the station was moved in fall 2018 to a location approximately 200 m downstream of the last location (Figure 3-3). Water level data were collected from 8 February 2018 to 26 December 2018 at Station K6.

3.3.1.2 Station K9 – Firebag River Tributary

Station K9 on Firebag River tributary FT-A has historically been stable and unaffected by beaver activity since 2005. However, in 2015, the station was backwatered by a downstream beaver dam and a second dam was discovered directly on top of the station orifice line, requiring that the orifice line be relocated approximately 5 m downstream. In 2016, both dams were abandoned and in August a major beaver dam was discovered approximately 70 m upstream of the station, resulting in the water level dropping below the monitoring equipment. The Golderwatch telemetry communication unit at Station K9 was removed in 2016 due to insufficient satellite signal in the densely-treed area near the station. Water levels were very low in 2017 and again dropped below the monitoring equipment, which had been adjusted for the 2016 low water levels. During the summer 2017 visit it was found that the Argo access had deteriorated significantly as large trees had fallen on the path. The site was unreachable in the fall because of inaccessibility by Argo and high-water levels in the Firebag River that prevented a helicopter landing on the usually shallow riverbed.

A helicopter was able to safely land on the ice during the winter 2018 field visit, and the station was dismantled. The station was re-installed during the spring visit approximately 2.6 km upstream of its original location.

3.3.1.3 Station K10 – Firebag River

Station K10 monitors the main stem of the Firebag River approximately 5 km downstream (north) of the Kearl northern lease boundary (Figure 2-1). Station K10 is located at the Kearl EIA hydrology assessment point called F2. This station has been hydrologically stable and unaffected by beaver activity since being established in 2005, as is typical of a station on a large river. The station has been inaccessible by Argo since spring 2016 due to large fallen trees blocking the access trail - the station has been reached by helicopter since the summer 2017 visit. During the summer 2017 visit, it was found that the station and local benchmarks had been damaged by fallen trees and the station was repaired and new benchmarks established. The field crew was unable to measure discharge during the spring 2018 field visit due to unsafe conditions from high river flows. The orifice line installed along the left bank (facing downstream) shifted twice in 2018: once between the winter and spring, and the second time just prior to the fall field visit (there was ice formation along the Firebag River in early October 2018 due to the cold fall weather conditions) likely due to ice effects or debris entrained in the flow catching on the line.

3.3.1.4 Station K11 – Muskeg River

Station K11 monitors the mainstem of the Muskeg River in Segment MRR-4, located just downstream (west) of the northwest boundary of the Kearl lease. Beaver activity observed during previous monitoring years continued at Station K11 in 2018. The station was moved to an alternate location in 2013 but was moved back to the original (2007 to 2012) location in 2014, in both cases due to changing beaver activity. Although beaver activity still exists at the original location, a long-term rating curve for the location makes producing a discharge time series easier than at a site without an established rating curve. Beaver dams upstream and downstream of the streamflow station caused backwater during the summer and fall 2017 and 2018 visits and may have temporarily cut off flows, as very low discharge was measured during these visits.

3.3.1.5 Station C4 – Muskeg River Climate Station

Climate monitoring Station C4 is located in the upper Muskeg River watershed approximately 200 m upstream of the new K6 hydrometric monitoring station installed in 2018 on Muskeg River upland tributary MT-5. The climate station includes a tipping bucket rain gauge, air temperature and atmospheric pressure sensor and datalogger. It is not connected to a telemetry system as the hydrometric stations are. During the spring visit, a graduated rain gauge was installed 2 m away from the tipping bucket gauge for backup but was found to be destroyed by wildlife during the summer visit. The air temperature sensor also malfunctioned and may have been damaged at the same time.

Climate data were collected from January to August 2018 at Station C4. Although the station is likely still functioning, the data for the remainder of the year could not be downloaded during the fall 2018 field visit due to communication cable issues and could not be included in this report.

3.3.2 2018 Monitoring Results

3.3.2.1 Station K6 – Muskeg River Tributary

The 2018 surveyed water levels and measured discharges at Station K6 are presented in Table 3-3. In 2018, Station K6 was affected by backwater due to a beaver dam downstream of the station, as well as an upstream dam creating overland flow that bypassed the gauge. The station was therefore moved to a location approximately 200 m downstream on 24 August (Figure 3-3). Due to backwater, the 2018 manual measurements were not useful additions to the station rating curve and shift-corrections were required to correct discharge time series records to the measured discharge values.

A new preliminary rating curve was created for this station based on the two measurements at the new location in August and October 2018, and this rating curve will be improved on in future monitoring years. Discharge was estimated by assuming a rating curve through the two measured values with a formula extended to higher and lower water levels using a linear equation. See Section 3.4.1.1. for rating curve details for the historical record at this station. Water level and discharge results for 2018 are provided in Figure 3.4. Redundant water level measurements were recorded during the open-water period with a HOBO logger, which agreed very well with the CFB stage values for the coincident period of record, and these data were used to fill the gap in the CFB data that occurred due to a battery connection problem. The change in station location is evident in Figure 3-4 on 24 August when the water level records shifted downward and a new preliminary rating curve was used to estimate discharge thereafter.

Table 3-3: Water Level and Discharge Measurements at Station K6, 2018

Date	Surveyed Water Level (m)	Measured Discharge (m^3/s)	Field Observations
10 March (old location)	98.721[(a)]	0.0018	Manual discharge and water level measured under ice. Ice shelf frozen 20 cm above water level.
17 May (old location)	98.995[(a)]	No measurement	Manual water level surveys performed. Flows were relatively high for this site; however, the current meter malfunctioned and no reliable discharge reading was obtained.
24 August (new location)	98.406	0.0006	Manual discharge and water level surveys performed.
18 October (new location)	98.585	0.0142	Manual discharge and water level surveys performed.

[(a)] Water levels affected by backwater from beaver activity downstream and overland flow from upstream dam.
Note: m = metres; m^3/s = cubic metres per second



Figure 3-3: Hydrometric Station K6 Muskeg River Upland Tributary at the New Location, 18 October 2018

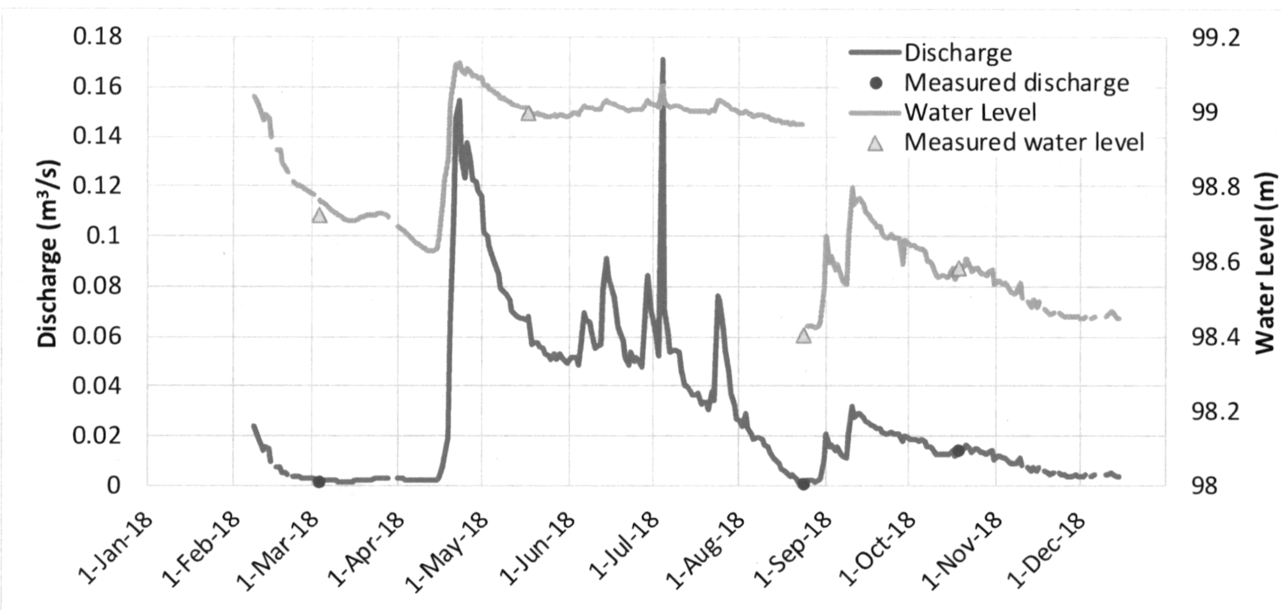


Figure 3-4: Water Level and Discharge Results for Hydrometric Station K6, 2018

3.3.2.2 Station K9 – Firebag River Tributary

Station K9 was determined to no longer be accessible by Argo due to a large number of fallen trees on the access route and inaccessible by helicopter without safe ice or low river water levels. In addition, a large beaver dam located approximately 70 m upstream of the station reduced the water level at the station to a point that was too low for the equipment to measure. Therefore, Station K9 was removed during the 2018 winter visit (8 March), when a helicopter was able to land on safe ice near the site, so that the station could be relocated in the spring, once the ground thawed sufficiently to allow re-installation. The GolderWatch telemetry unit at this station was previously removed in 2016 due to the inability to transmit a signal through the thick vegetation cover. In spring 2018, Station K9, including the CFB and telemetry unit, was re-installed during the spring field visit at a location approximately 2.6 km upstream of the original site, where the new site is accessible by Argo or helicopter (Figure 3-5). As of fall 2018, no beaver activity has been observed at the new location.

A battery issue occurred at Station K9 shortly after the 2018 spring field visit that resulted in no CFB data being stored, and caused a data gap from 12 June to 23 August. The HOBO logger that was installed as a backup was also found to have problems when data were downloaded during the fall field visit, thus this logger could not be used to fill the data gap.

The surveyed water level and measured discharge data for Station K9 are presented in Table 3-4. No measurements were taken during the winter event due to issues at the old station location. The 2018 hydrograph is provided in Figure 3-6. Stage-discharge rating curves for the period of record including 2018 are provided in Section 3.4.1.2.

Table 3-4: Water Level and Discharge Measurements at Hydrometric Station K9, 2018

Date	Surveyed Water Level (m)	Measured Discharge (m^3/s)	Notes
8 March	not measured	not measured	Station dismantled for relocation.
16 May (new location)	99.401	0.0591	Installed CFB hydrometric station at new location, manual discharge and water level surveys performed.
24 August (new location)	99.315	0.0112	Manual discharge and water level surveys performed.
15 October (new location)	99.393	0.381	Manual discharge and water level surveys performed.

Note: m = metres; m^3/s = cubic metres per second



Figure 3-5: Hydrometric Station K9 Reinstalled at the New Location on 16 May 2018

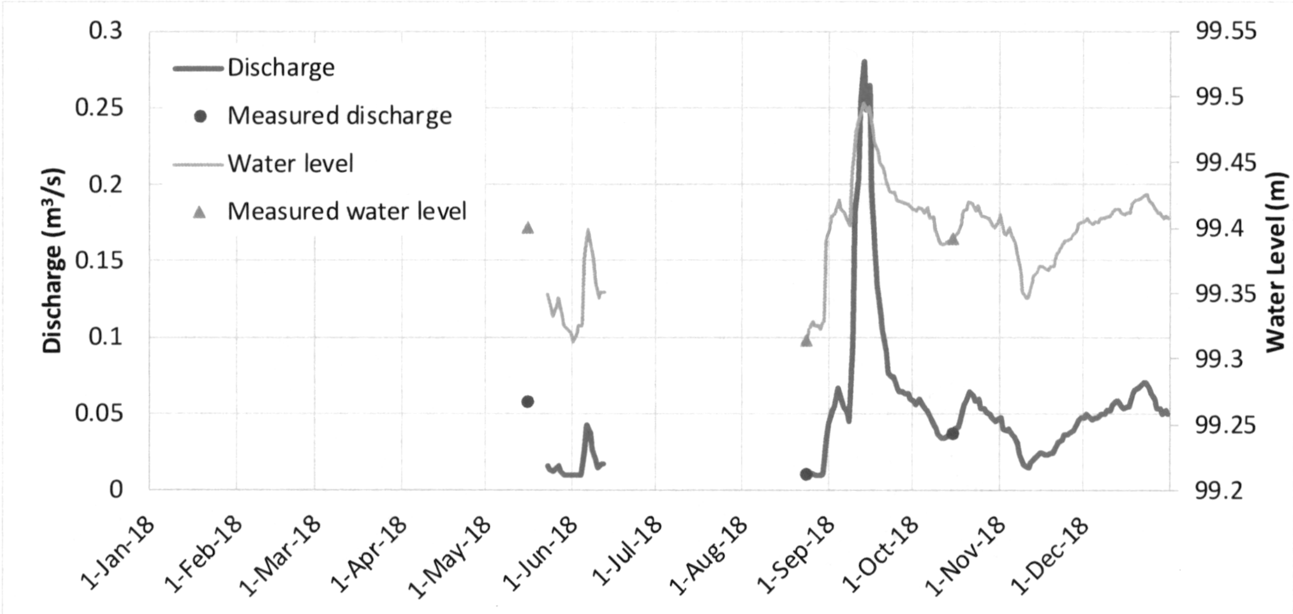


Figure 3-6: Water Level and Discharge Results for Hydrometric Station K9, 2018

3.3.2.3 Station K10 – Firebag River

Station K10 became inaccessible by Argo after the March 2016 visit. Visits to this station resumed in August 2017 when helicopter use was granted on site. All visits in 2018 were completed by helicopter, although the summer visit was delayed because the helicopter was grounded due to weather conditions during the regular visit. An aerial photograph of the monitoring location during ice-covered conditions is shown in Figure 3.-7.

During the spring event, the station had to be repaired because the orifice line was snapped near the bubbler station, likely by ice carrying the end of the orifice line away during the spring melt. During the fall visit in October, it was found that ice pans had formed during an early freeze-up and had dislodged the end of the orifice line again and it was moved approximately 20 m downstream of its original location. The water level data in 2017 were shifted upward by 0.35 m to match the previous rating curve and the new benchmark elevation established. The 2018 water level records and stage survey results were also corrected upward by the same amount to provide stage results that tie into the previous year. Notwithstanding the periodic challenges at this station, it remains the most reliable of the four monitoring stations and is considered to provide reliable data in most years.

The surveyed water level and measured discharge data are presented in Table 3-5. Stage-discharge rating data for 2018 are provided in Appendix II. Water level and discharge results are provided in the hydrograph (Figure 3-8).

Table 3-5: Water Level and Discharge Measurements at Hydrometric Station K10, 2018

Date (2018)	Surveyed Water Level (m)	Corrected Stage (m)	Measured Discharge (m^3/s)	Notes
8 March	96.965	Add 0.35 m	4.542	Manual discharge and water level surveys performed under ice conditions
14 May	97.087	Add 0.35 m	not measured	Unable to measure discharge due to high flow conditions and resulting safety issues, manual water level survey completed
5 September	96.635	Add 0.35 m	8.782	Manual discharge and water level surveys performed
15 October	96.762	Add 0.35 m	11.495	Manual discharge and water level surveys performed

Note: m = metres; m^3/s = cubic metres per second



Figure 3-7: Aerial Photo of Hydrometric Station K10, 8 March 2018

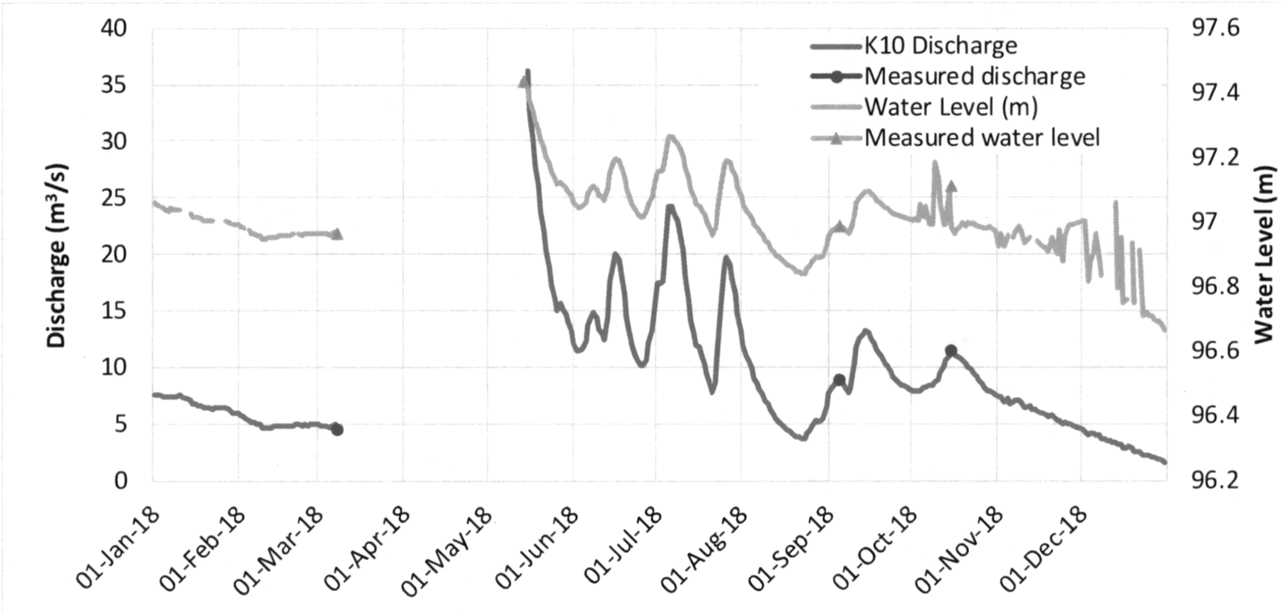


Figure 3-8: Water Level and Discharge Results for Hydrometric Station K10, 2018

3.3.2.4 Station K11 – Muskeg River Lowland

Manual flow and water level measurements were taken at Station K11 during the four seasonal site visits. However, flows during the winter, summer and fall field trips were very low, despite water levels that were close to or higher than the spring visit (Figure 3-9), indicating potential issues with water impounded by downstream beaver dams. There has typically been a lot of beaver activity along the entire river reach and this was observed again at Station K11 in 2018. Due to beaver activity and dams both upstream and farther downstream of the station, it is unlikely that moving the station will result in a better monitoring location at this time. Therefore, the decision was made to retain the current location and to continue to monitor the beaver activity, while making shift corrections in the rating curve to account for backwater from the downstream dams.

The surveyed water level and measured discharge data are presented in Table 3-6. Stage-discharge rating curves for the period of record (including 2018) are provided in Appendix II. Stage and discharge results for 2018 are provided in the hydrograph (Figure 3-10). Discharge records were corrected for 2018 using stage shifts to measured stage and discharge values and the corrected values are considered adequate to represent flow conditions from 15 May to 17 October. The daily mean peak flow was 2.1 m^3/s and occurred 5 May during spring freshet.

Table 3-6: Water Level and Discharge Measurements at Hydrometric Station K11, 2018

Date	Surveyed Water Level (m)[(a)]	Measured Discharge (m^3/s)	Notes
9 March	99.198	0.0006	Manual discharge and water level surveys performed.
15 May 15	99.485	1.23	Manual discharge and water level surveys performed.
22 August	99.447	0.06	Manual discharge and water level surveys performed.
17 October	99.720	0.16	Manual discharge and water level surveys performed.

(a) Water levels backwatered throughout 2018 by beaver activity.

Note: m = metres; m^3/s = cubic metres per second



Figure 3-9: Photo of Flooding at Hydrometric Station K11, 17 October 2018

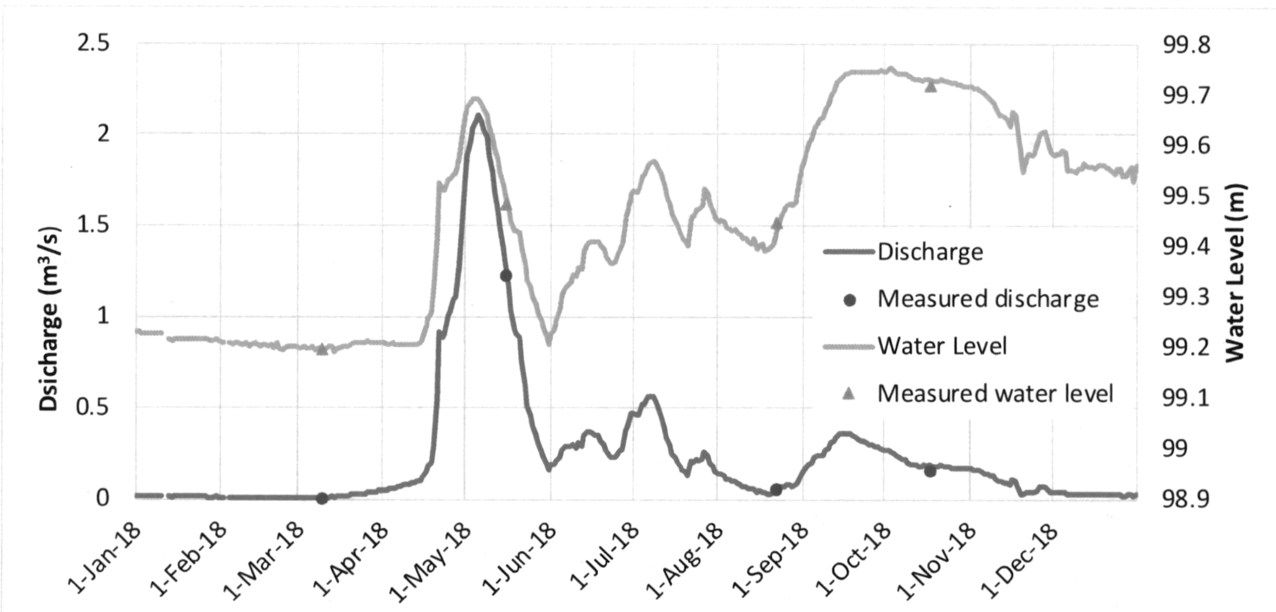


Figure 3-10: Water Level and Discharge Results for Hydrometric Station K11, 2018

3.3.2.5 *Station C4 – Muskeg River Watershed Climate Station*

Climate Station C4 is located in the Muskeg River watershed upland area beside Muskeg River upland tributary MT-5 (Figure 2-1). The station was placed in a location that is considered representative of upland areas. Climate Station C4 was operational throughout the 2018 monitoring season but malfunctioning cables did not allow for the station data to be downloaded during the fall field visit so that data is currently available until 23 August. In addition, a graduated rain gauge was installed at the station in spring 2018 to provide a total volume of precipitation over time between field visits (this would provide a comparison with the total TBRG results); however, it was found destroyed during the summer field visit. The temperature sensor began presenting unrealistic temperature readings in April 2018 and therefore the data was not for the rest of 2018. The plots of daily mean precipitation and daily mean air temperature for 2018 are presented in Figure 3-11.

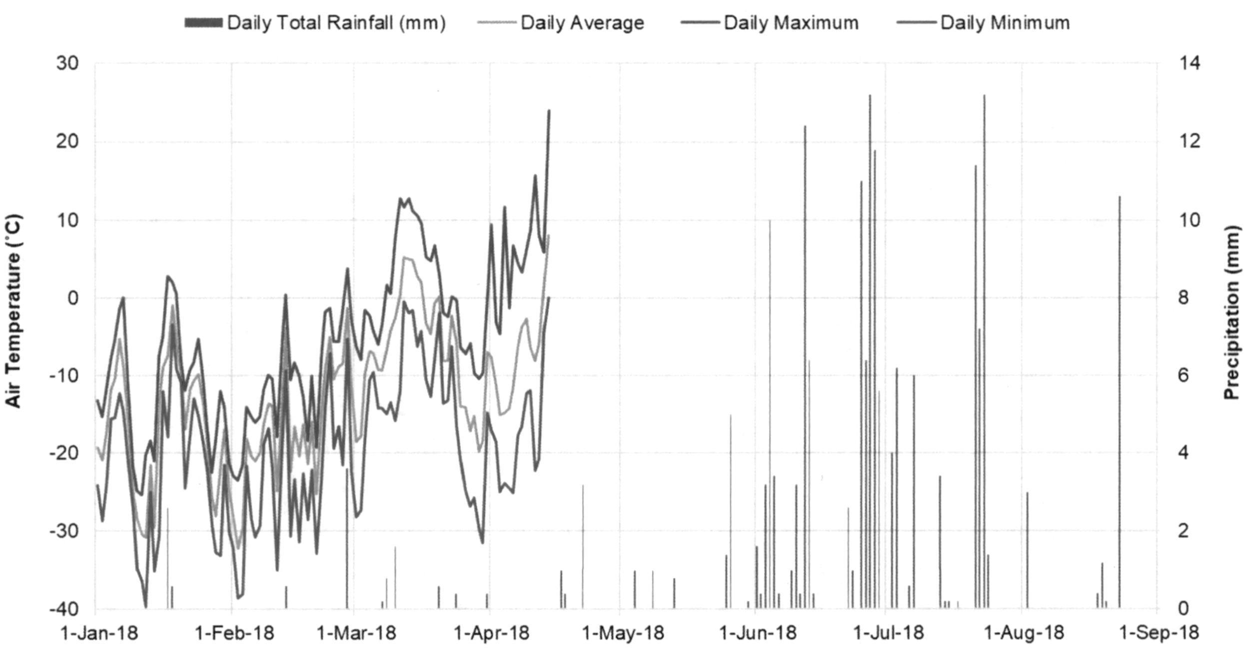


Figure 3-11: Air Temperature and Precipitation Records for Climate Station C4, 2018

3.4 Kearl Hydrology and Climate Data Summary

3.4.1 Hydrology Monitoring Data

Historical data collected for the Project hydrology monitoring stations are provided in this section. Results include the following:

- summary of field monitoring conditions at the hydrometric stations over the period of record;
- summary of annual and monthly flow statistics; and
- discharge hydrographs for each station for the available period of record.

A summary of annual and monthly streamflow results for the Kearl hydrology monitoring stations is provided in Table 3-7. Hydrographs for the available records are provided in Figures 3-12 to 3-15. Daily mean flows for each station are provided in Appendix I, and rating curves are shown in Appendix II.

Table 3-7: Summary of Open-Water Period Flow Statistics at the Hydrometric Stations

Mean Discharge Statistics (m^3/s)	K6 Muskeg River Upland Tributary	K9 Tributary of Firebag River	K10 Firebag River [(b)]	K11 Muskeg River Lowland
Period of Record Included [(a)]	2012 to Present	2012 to Present	2008 to Present	2012 to Present
January	0.001	No data	4.623	0.016
February	0.004	No data	4.763	0.015
March	0.001	No data	5.144	0.024
April	0.074	0.051	12.451	0.673
May	0.098	0.044	29.779	1.131
June	0.091	0.038	23.104	1.136
July	0.086	0.046	17.894	0.652
August	0.016	0.046	10.086	0.286
September	0.122	0.076	15.336	0.402
October	0.042	0.067	13.071	0.363
November	0.021	0.042	7.942	0.141
December	0.010	0.046	5.320	0.029
Mean Annual (% of record complete)	0.061 (83% complete record)	0.054 (38% complete record)	13.093 (91% complete record)	0.457 (70% complete record)
Mean Open-Water Season (April 15 – Nov 14)	0.081	0.055	17.625	0.650
Mean Ice-Covered Season (Nov 15 – Apr 14)	0.022	0.046	5.375	0.055

[(a)] Prior to 2014, when the CFB systems and telemetry were installed for the hydrometric stations, the Kearl hydrology stations only monitored water levels and discharge during the open-water season, although field discharge measurements occurred in March each year.

[(b)] Statistics for Station K10 are based on discharge observed at Station K10 and also derived from RAM Station S43 and S27, in order of preference, for the periods that data are missing at Station K10.

3.4.1.1 Station K6 – Muskeg River Tributary

Stage and discharge results for Station K6 (Muskeg River tributary MT-5) along with field measurements are provided in Figure 3-12. The station became backwatered in summer 2016 and remained that way until it was moved in spring 2017 to a new location. Flows in 2015, 2017 and 2018 were relatively low compared to flows in 2014. Maximum daily mean discharge was 0.62 m^3/s observed in spring 2014. Although higher flood events likely occurred in 2012 in response to heavy rainfall events in July and September, the magnitude of peak flows can not be verified as it is an extrapolation beyond the rating curve.

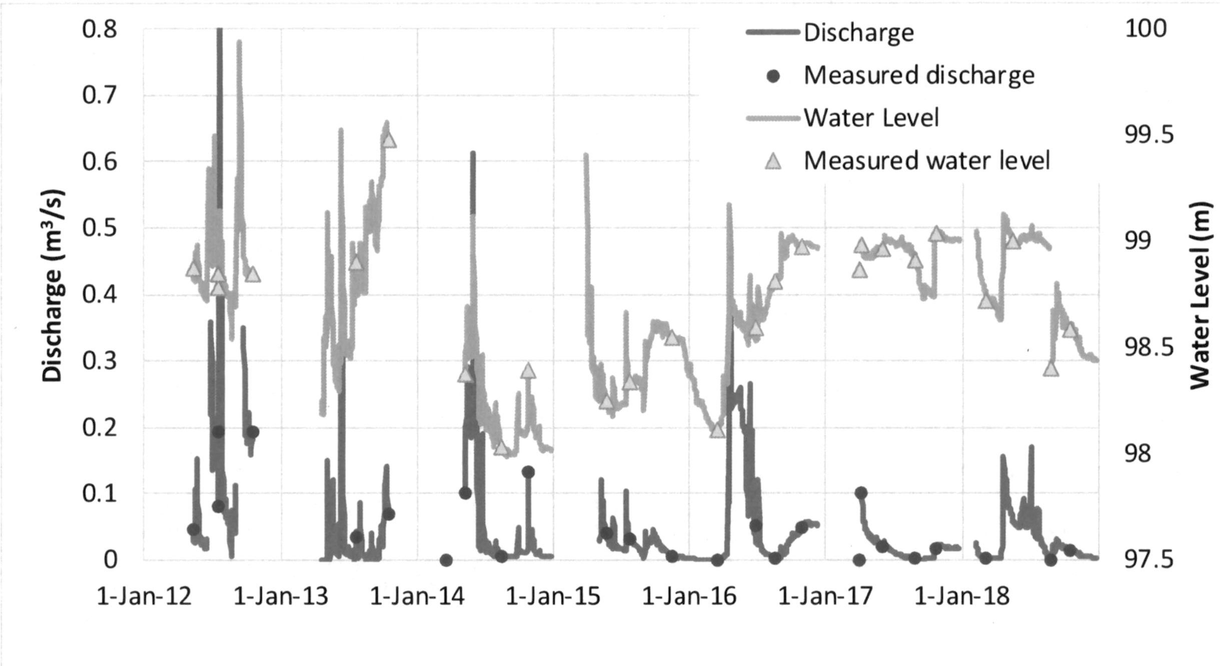


Figure 3-12: Stage and Discharge Results for Station K6, 2012 to 2018

3.4.1.2 Station K9 – Firebag River Tributary

Stage and discharge results for Station K9 (Firebag River Tributary FT-A) along with field measurements are provided in Figure 3-13. The original station that was located near the watercourse mouth became backwatered in 2017 and was moved in spring 2017 to a new location 2.6 km farther upstream. Therefore, the stage values in 2018 represent a new gauging location. Maximum daily mean flow was 0.28 m^3/s observed in spring 2018.

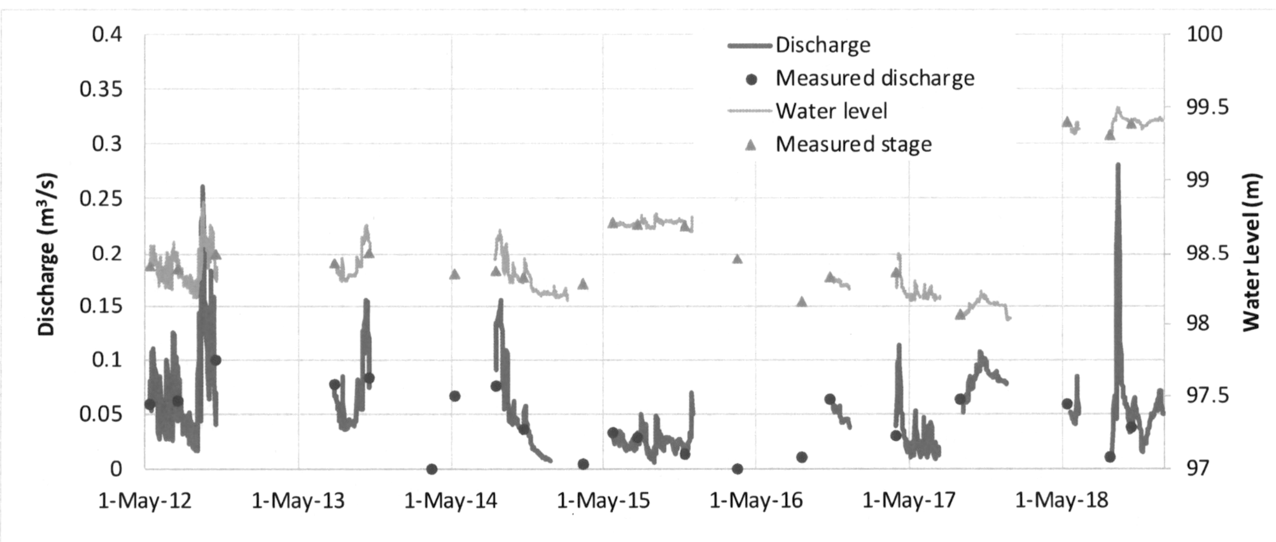


Figure 3-13: Stage and Discharge Results for Station K9, 2012 to 2018

3.4.1.3 Station K10 – Firebag River

Stage and discharge results for Station K10 on the Firebag River along with field measurements are provided in Figure 3-14. A year-round record was derived for this station based on incorporating recorded flows at two other stations along the Firebag River. The discharge results for the years 2008 to 2018 are included in Section 3.5.2.2 of this report, as this station coincides with the location of Kearl EIA assessment node F2. The maximum daily mean discharge was 76.4 m^3/s during spring freshet on 2 June 2014, and a similar sized event occurred in September 2012.

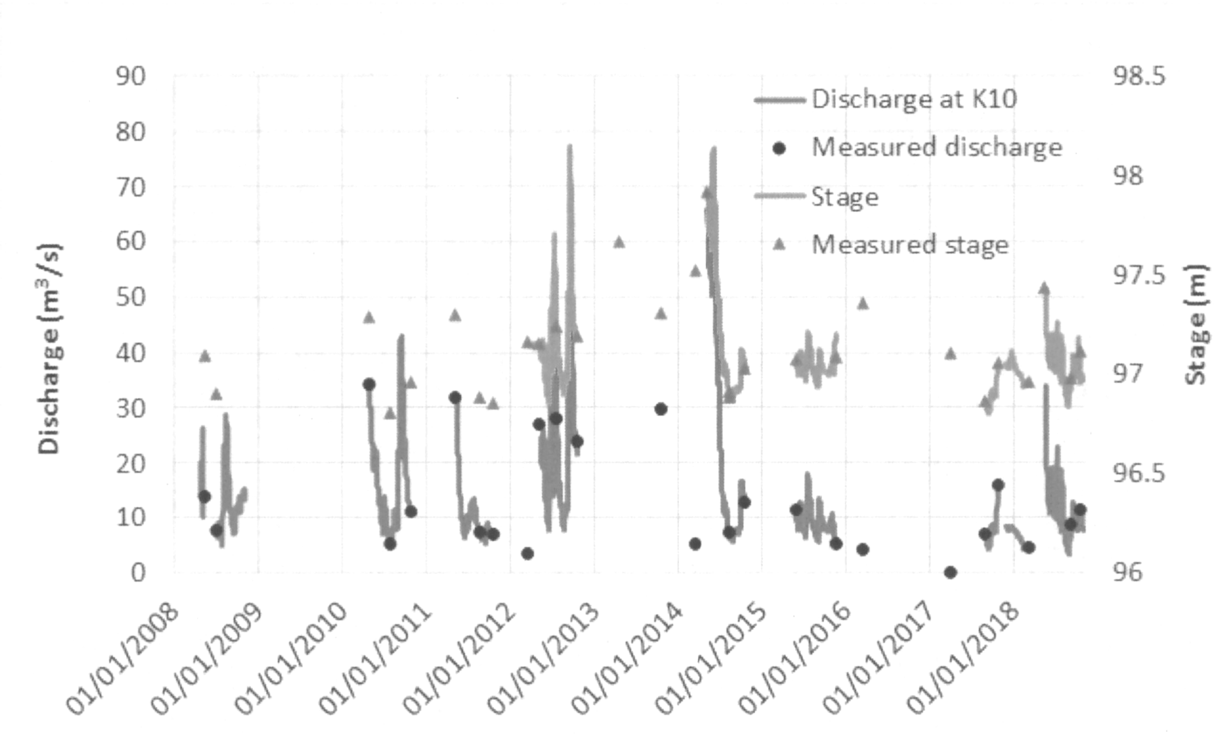


Figure 3-14: Stage and Discharge Results and Field Measurements for Station K10, 2008 to 2018

3.4.1.4 Station K11 – Muskeg River

Stage and discharge results for Station K11 (Muskeg River lowland) along with field measurements are provided in Figure 3-15. The station has been periodically backwatered by beaver dam activity that has occurred both upstream and downstream of the station. Beaver dams upstream of the station have occasionally reduced water levels recorded at the station. Peak daily discharge during the 2013 spring flood was estimated to be just below 6.0 m^3/s. Muskeg River flows were generally low between 2015 and 2017, although the spring peak flow in 2017 was moderate. Flows were generally higher than average in 2012 to 2014.

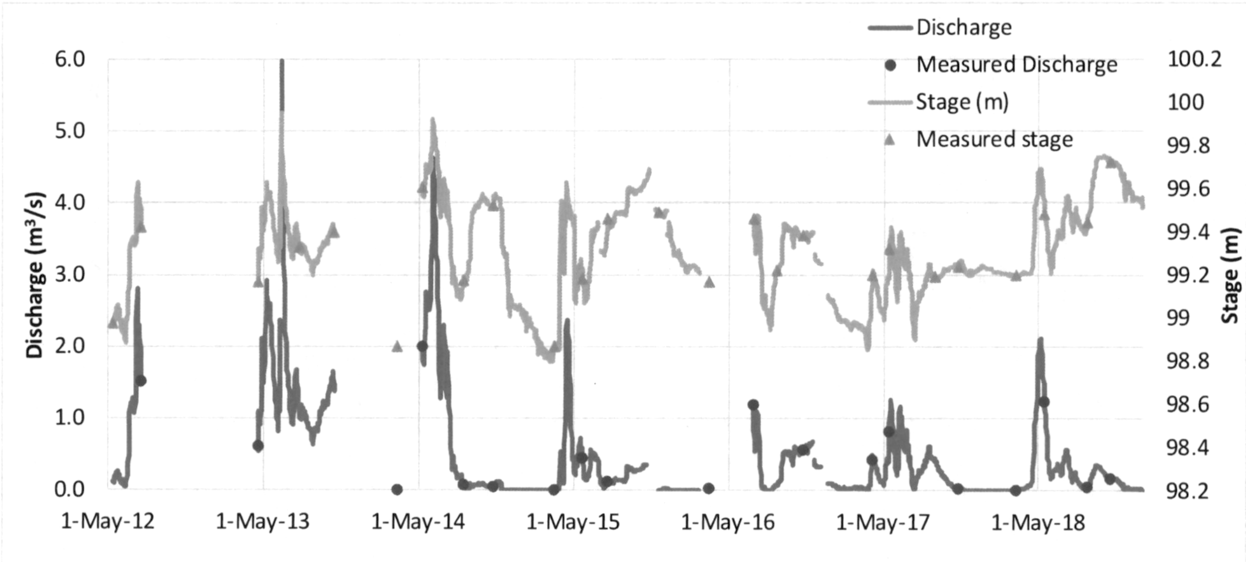
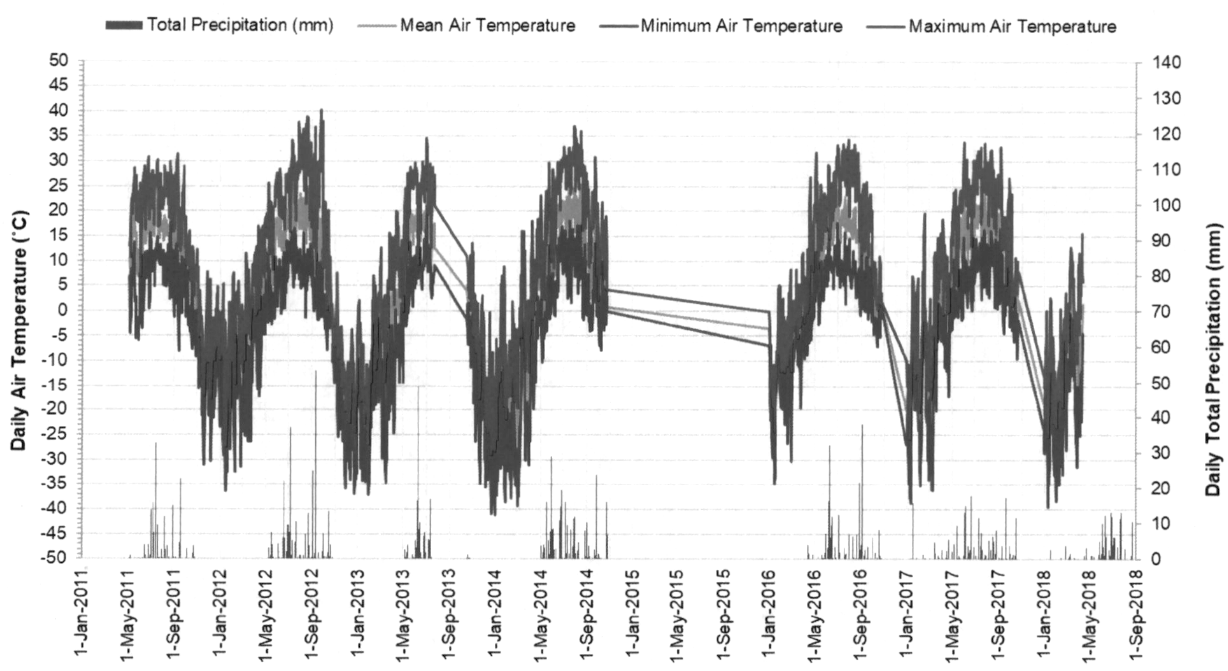


Figure 3-15: Stage and Discharge Results for Station K11, 2012 to 2018

3.4.1.5 *Climate Monitoring Data*

Air temperature and daily total rainfall from the TBRG at Station C4 are provided in Figure 3-16 for each year of record (2011 to 2018). Prior to 2011, rainfall only data were collected at Climate Station C3, with limited data available in 2010 (Figure 3-17).



Note: Climate data was not available in 2015.

(2) Climate monitoring station C4 was established in 2011 and was upgraded to collect both rainfall and air temperature data. No air temperature was collected before 2011. See Figure 3.3-6 for the 2010 rainfall data from climate station C3.

Figure 3-16: Climate Station C4 Air Temperature and Precipitation Data, 2011 to 2018

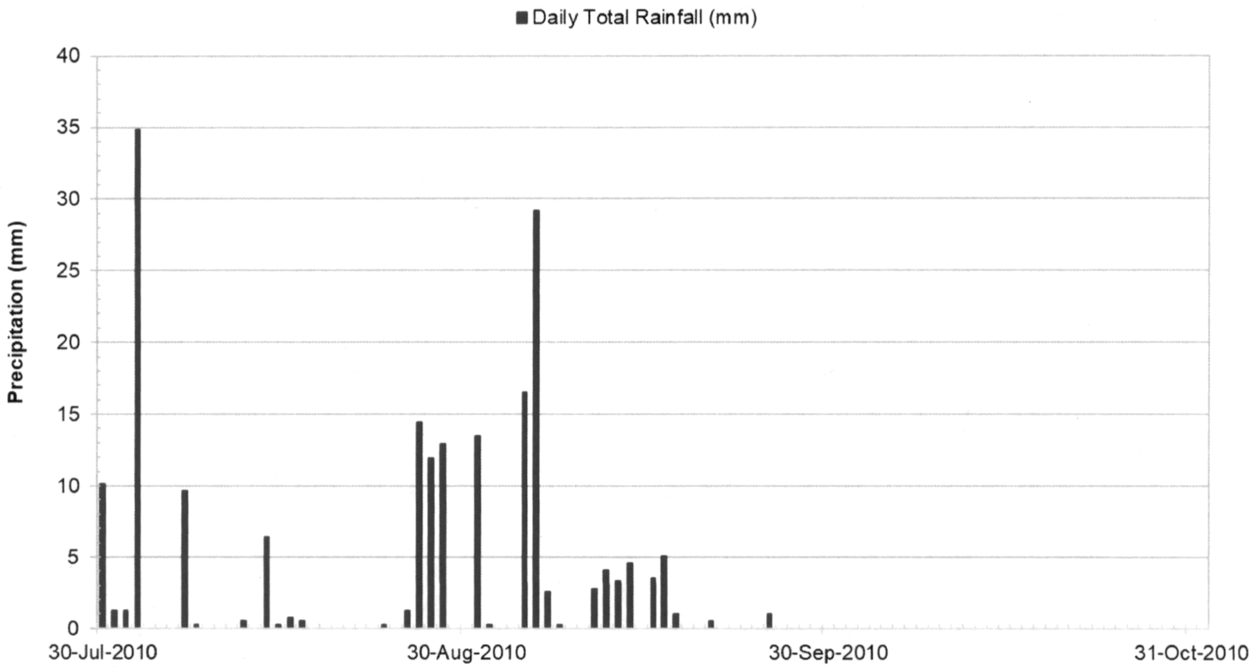


Figure 3-17: Climate Station C3 Precipitation Data, 2010

Cumulative rainfall amounts monitored at Kearl Climate Station C4 are shown in Figure 3-18 for the years 2011 to 2014 and 2016 to 2018. The years 2013 and 2018 only have partial data but the other years have a nearly complete record from 1 May to 31 October and provide a good representation of total rainfall amounts. The TBRG results would not provide accurate precipitation amounts in winter as the gauge is not designed for measuring snowfall amounts.

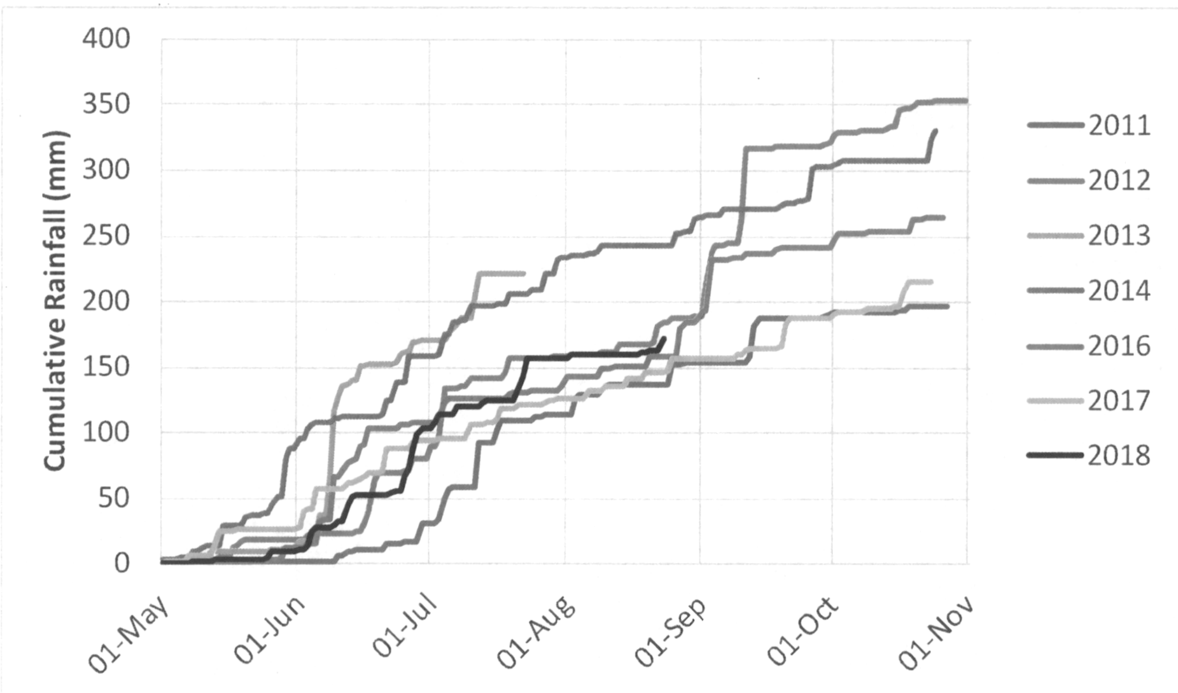


Figure 3-18: Kearl Climate Station C4 Cumulative Daily Total Rainfall Amounts (1 May to 31 October), 2011 to 2018

Total seasonal rainfall at Kearl Station C4 is compared with total annual precipitation at a nearby RAM climate station (Aurora Station C1), which is about 20 km southwest of Kearl Station C4. The total rainfall amounts at Kearl C4 are about 75% of the total precipitation for the hydrological year at RAM Station C1 for the coincident period of record (Figure 3-19) (only the complete seasonal records are shown in Figure 3-18, therefore 2013 and 2018 were left out). Mean precipitation at RAM Station C1 was 361 mm, and years with higher than average precipitation include 1999 to 2003, 2005, 2012 to 2014, and 2016.

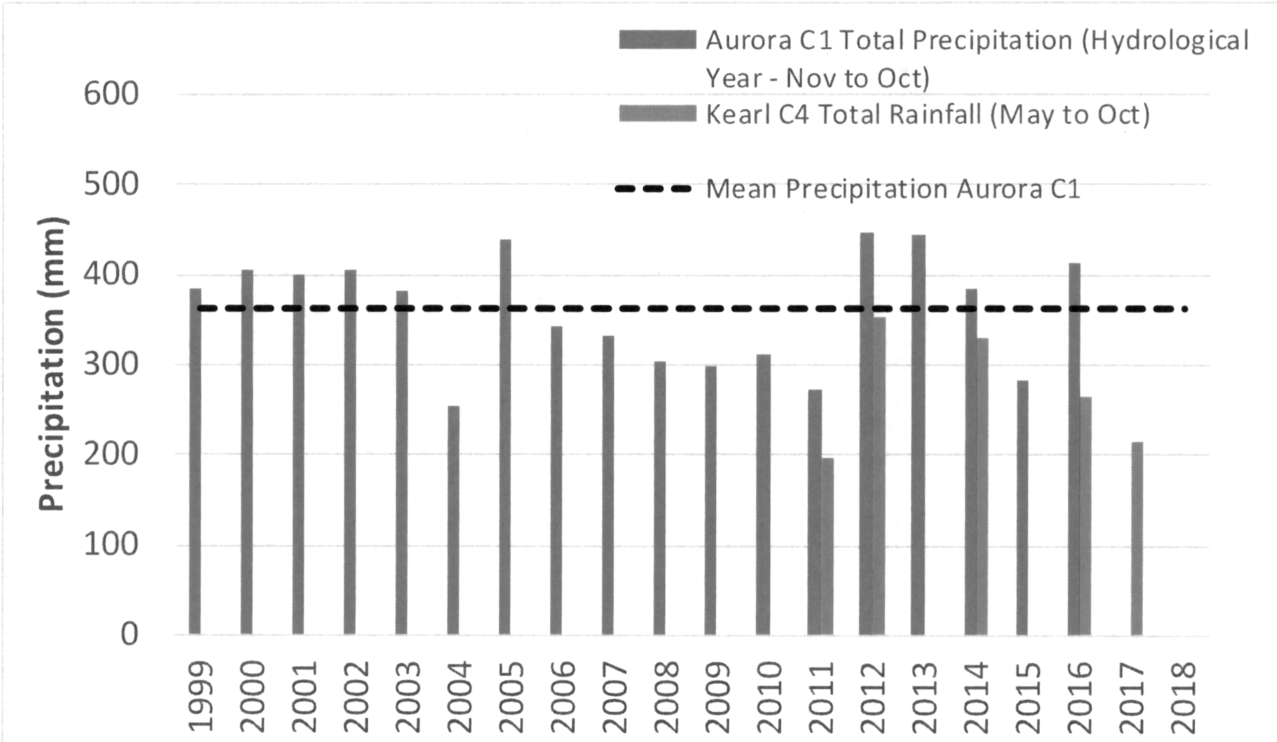


Figure 3-19: Total Precipitation at RAM Station C1 (Hydrological Year) Compared with Seasonal Total Rainfall Amounts at Kearl Station C4

3.4.1.6 Kearl Field Data Summary

Historical water level and discharge data collected in the field at each station, as well as observations of the station conditions during the field visits are provided in Tables 3-8 to 3-11.

Table 3-8: Historical Field Measurements at Hydrometric Station K6 – Muskeg River Tributary, 2012 to 2018

Measurement Date	Discharge [m³/s]	Water Level Elevation[(a)] (m)	Station Conditions
2012-03-17	n/a	n/a	Channel frozen to the bottom.
2012-05-09	0.045	98.87	Monitoring station installed.
2012-08-22	0.079	98.784	Discharge and water levels surveyed.
2012-10-17	0.193	98.842	Evidence of extreme flows on channel floodplain.
2013-03-17	n/a	n/a	Channel frozen to the bottom.
2013-04-17	n/a	n/a	Channel frozen to the bottom.
2013-07-22	0.035	98.9	Open water.
2013-10-17	0.067	99.474	Evidence of beaver activity affecting the channel.
2014-03-18	0	n/a	No flow, frozen to bottom.
2014-05-10	0.1	98.372	Station moved upstream approximately 200 m.
2014-08-15	0.005	98.028	Very low flow rate.
2014-10-24	0.132	98.395	CFB unit installed.
2015-03-13	0	none	No flow, frozen to bottom.
2015-05-22	0.039	98.249	Manual discharge and water level surveys performed.
2015-07-25	0.03	98.338	Manual discharge and water level surveys performed.
2015-11-16	0.004	98.549	Manual discharge and water level surveys performed.
2016-03-17	0	98.116	No flow, frozen except for 0.1 m water depth.

Table 3-8: Historical Field Measurements at Hydrometric Station K6 – Muskeg River Tributary, 2012 to 2018

Measurement Date	Discharge [m^3/s]	Water Level Elevation[(a)] (m)	Station Conditions
2016-06-27	0.051	98.595	Manual discharge and water level surveys performed.
2016-08-20	0.002	98.808	Manual discharge and water level surveys performed - Water levels affected by backwater from beaver activity downstream.
2016-10-26	0.004	98.976	Manual discharge and water level surveys performed - Water levels affected by backwater from beaver activity downstream.
2017-04-06	0.101	98.977	Manual discharge and water level measured under ice. Secondary discharge measurement at main overland flow channel, included in discharge total.
2017-05-20	0.0202	98.959	Manual discharge and water level surveys performed. Attempted secondary discharge at main overland flow channel (-0.0240 m^3/s), not included in discharge total.
2017-08-29	0.0012	98.913	Manual discharge and water level surveys performed. No overland flow.
2017-10-23	0.0168	99.032	Manual discharge and water level surveys performed. Secondary discharge measurement at main overland flow channel, included in discharge total. Water levels affected by backwater from beaver activity downstream and overland flow from upstream dam throughout 2017.
2018-03-10	0.0018	98.721	Manual discharge and water level measured under ice. Ice shelf frozen 20 cm above water level, Water levels affected by backwater from beaver activity downstream and overland flow from upstream dam.
2018-05-17 (old location)	Not measured	98.995	Manual water level surveys performed. Water levels affected by backwater from beaver activity downstream and overland flow from upstream dam.
2018-08-24 (new location)	0.0006	98.406	Manual discharge and water level surveys performed.
2018-10-18	0.0142	98.585	Manual discharge and water level surveys performed.

[(a)]Water level elevations were tied to a temporary benchmark elevation of 100 m.

Note: n/a = data not available.

Table 3-9: Historical Field Measurements for Hydrometric Station K9 – Firebag River Tributary, 2012 to 2018

Measurement Date	Discharge [m³/s]	Water Level Elevation[a] (m)	Station Conditions
2012-03-16	n/a	n/a	Channel frozen to bottom.
2012-05-10	0.593	98.406	Open water, monitoring station installed.
2012-07-19	0.062	98.386	Open water.
2012-10-17	0.01	98.493	Open water.
2013-03-01	n/a	n/a	Poor road conditions prevented site access.
2013-04-01	n/a	n/a	Poor road conditions prevented site access.
2013-07-25	0.077	98.429	Open water.
2013-10-17	0.083	98.505	Open water.
2014-03-16	0	n/a	Frozen to bottom, no flow.
2014-05-10	0.066	98.35	Hobo unit installed.
2014-08-15	0.076	98.376	CFB unit installed.
2014-10-23	0.037	98.321	Hobo unit removed.
2015-03-13	0.005	98.276	Very low flow under ice, unmeasurable - flow estimated due to unsafe ice conditions.
2015-05-23	0.033	98.709	Manual discharge and water level surveys performed.
2015-07-23	0.029	98.704	Manual discharge and water level surveys performed
2015-11-14	0.013	98.666	Manual discharge and water level surveys performed - new beaver dam discovered at station location.
2016-03-17	0	98.461	Standing water under-ice, no flow.
2016-06-29	0	not measured	Water ponding at different levels, no flow.
2016-08-19	0.011	98.16	Manual discharge and water level surveys performed.
2016-10-25	0.063	98.324	Manual discharge and water level surveys performed, Station was backwatered from beaver activity throughout 2016.
2017-03-31	0.0309	98.362	Manual discharge and water level measured under ice.
2017-08-31	0.064	98.07	Manual discharge and water level surveys performed, discharge measurement poor due to limited flow (0.1 m depth), Station water level was inhibited due to upstream beaver activity throughout 2017.
2018-05-16	0.0591	99.401	Built and launched station at new location, manual discharge and water level surveys performed.
2018-08-24	0.0112	99.315	Manual discharge and water level surveys performed.
2018-10-15	0.381	99.393	Manual discharge and water level surveys performed.

[a]Water level elevations were tied to a temporary benchmark elevation of 100 m.

Note: n/a = data not available.

Table 3-10: Historical Field Measurements at Hydrometric Station K10 – Firebag River, 2012 to 2018

Measurement Date	Discharge [m^3/s]	Water Level Elevation[a] (m)	Station Conditions
2012-03-16	3.31	97.168	Complete ice cover.
2012-05-09	27.1	97.158	Monitoring station installed.
2012-07-18	28.1	97.245	Open water.
2012-10-16	24.1	97.195	Open water.
2013-03-01	n/a	n/a	Unsafe trail conditions prevented the crew from reaching the site.
2013-04-18	n/a	97.661	Monitoring station installed, complete ice cover, ice too thick for measurement.
2013-07-24	n/a	NA	Bad road conditions prevented the crew from reaching this site.
2013-10-18	29.7	97.311	Open water, logger found on shore.
2014-03-16	5.094	97.521	Ice cover measurement.
2014-05-06	n/a	97.911	Conditions unsafe to perform measurement.
2014-08-12	7.21	96.89	CFB unit installed.
2014-10-21	12.656	97.032	Hobo unit removed.
2015-03-14	4.58	97.319	Manual discharge and water level surveys performed.
2015-05-26	11.5	97.079	Manual discharge and water level surveys performed - orifice line reattached to orifice block on stream bottom.
2015-07-01	n/a	n/a	The crew could not access the site.
2015-11-17	5.3	97.086	Partial ice cover measurement.
2016-03-18	4.243	97.357	Manual discharge and water level surveys performed.
2017-08-28	6.8413	96.87	Station repaired, new benchmark established, manual discharge and water level surveys performed.
2017-10-26	15.92	97.06	Manual discharge and water level surveys performed.
2018-04-08	4.5417	96.965	Manual discharge and water level surveys performed under ice conditions.
2018-05-14	n/a	97.087	Unable to measure discharge due to high flow conditions, manual water level survey completed.
2018-09-05	8.7818	96.635	Manual discharge and water level surveys performed.
2018-10-15	11.4954	96.762	Manual discharge and water level surveys performed.

[a]Water level elevations were tied to a temporary benchmark elevation of 100 m.

Note: n/a = data not available.

Table 3-11: Historical Field Measurements at Hydrometric Station K11 – Muskeg River, 2012 to 2018

Measurement Date	Discharge [m^3/s]	Water Level Elevation[a] (m)	Station Conditions
2012-03-14	n/a	n/a	Ice conditions unsafe to measure discharge.
2012-05-10	0	98.977	Monitoring station installed, malfunction of measurement gear.
2012-07-18	1.51	99.423	Open water.
2012-10-17	n/a	n/a	Water level too deep to safely wade, increased beaver activity, logger missing.
2013-03-14	0.087	99.654	Ice cover discharge measurement taken at the original site.
2013-04-19	0.615	99.165	Ice measurement, station moved to new location and benchmarks established.
2013-07-24	n/a	99.326	Not measured, area flooded and water too deep to wade.
2013-10-17	n/a	99.55	Not measured, area flooded and water too deep to wade.
2014-03-14	0.003	98.866	Ice cover measurement.
2014-05-08	1.995	99.607	ADP measurement.
2014-08-14	0.084	99.176	CFB unit installed.
2014-10-22	0.044	99.521	Hobo unit removed.
2015-03-17	0.01	98.865	Manual discharge and water level surveys performed.
2015-05-22	0.449	99.179	Manual discharge and water level surveys performed.
2015-07-20	0.13	99.457	Manual discharge and water level surveys performed - new beaver dam present.
2015-11-15	n/a	99.489	Ice conditions, unsafe to perform measurement.
2016-03-15	0.023	99.169	Manual discharge and water level surveys performed.
2016-06-28	1.19	99.463	Manual discharge and water level surveys performed.
2016-08-21	0	99.221	Manual discharge and water level surveys performed - new beaver dam present.
2016-10-24	0.57	99.379	Manual discharge and water level surveys performed.
2017-04-05	0.4245	99.195	Manual discharge and water level surveys performed.
2017-05-15	0.8284	99.322	Manual discharge and water level surveys performed.
2017-09-01	-0.0631	99.193	Manual discharge and water level surveys performed - impounded water with negative flow, not included in rating curve.
2017-10-24	0.0272	99.239	Manual discharge and water level surveys performed – impounded water with insignificant flow, not included in rating curve. Water levels affected by beaver activity throughout 2017.
2018-04-09	0.0006	99.198	Manual discharge and water level surveys performed.
2018-05-15	1.23	99.485	Manual discharge and water level surveys performed.
2018-08-22	0.06	99.447	Manual discharge and water level surveys performed.
2018-10-17	0.16	99.72	Manual discharge and water level surveys performed. Water levels affected by beaver activity throughout 2018.

[a]Water level elevations were tied to a temporary benchmark elevation of 100 m.

Note: n/a= data not available.

3.5 Evaluation of Regional Flow Trends and Comparison to Kearl EIA Predictions

3.5.1 Introduction

This section presents an analysis of trends in hydrologic parameters (flow and water levels) and a comparison with these parameters as presented in the Kearl EIA (Imperial Oil 2005) Application Case for the 2007 snapshot. At the time of writing, the EIA snapshots represent primarily a reference point for the analysis, since they were intended to reflect mining conditions that are currently over 10 years in the past. The 2007 snapshot is used as the next snapshot presented in the EIA is the year 2044, and therefore reflects development conditions that are not considered relevant to the measured data contained in this report.

The regional data presented in the section are from selected RAM stations, the Kearl hydrology monitoring program, and WSC stations. The hydrologic parameters presented in the Kearl EIA Application Case were based on simulated flows using Hydrological Simulation Program - Fortran (HSPF) model. The long-term flow statistics of recorded water levels and flows at selected RAMP hydrometric stations are also summarized.

The Kearl EIA includes the Kearl development along with other existing and approved projects. The mine development schedules for these projects as presented in the Kearl EIA are shown in Table 3-12.

Table 3-12: Mine Development Schedules for Kearl EIA Application Case Projects

Mine Activity	Aurora North Mine	Aurora South Mine	Jackpine Mine – Phase 1	Muskeg River Mine	Kearl Project
Commencement of Construction	1998	2008	2005	1999	2007
Commencement of Mining	2001	2012	2010	2002	2010
End of Mining	2040	2041	2031	2022	2060
Closure	2049	2050	2040	2031	2065

The actual schedules of some of the projects are not the same as what were assumed in the Kearl EIA (Imperial Oil 2005), hence, some of the differences between the results of model predictions and the monitoring data are attributed to the difference in the assumptions used during the Kearl EIA assessment regarding the various project schedules. For example, constructions of the Kearl and Aurora South Mine were not initiated in 2007 and 2008, respectively, and development of Jackpine Mine Phase 1 has been slower than expected.

3.5.2 Evaluation Methods

3.5.2.1 Flows and Water Levels Predicted in the Kearl EIA

The Kearl surface water hydrology EIA focused on addressing changes in flows in the watercourses downstream of Kearl (Muskeg River and Wapasu Creek) and changes in water balance of Kearl Lake.

The effects of the Project on hydrologic conditions in the receiving watercourses and waterbodies vary in time and space. The major project activities that affect the hydrologic conditions include muskeg drainage, overburden dewatering, closed-circuit areas and stream diversions. To date, the overburden dewatering has not contributed to water released to the Muskeg River watershed.

The continuous HSPF model was used to derive simulated flows series for streams in natural, disturbed and reclaimed areas. Flow statistics for the local streams and lakes was derived based on simulated flows from 1954 to 2003.

The sources of climate and hydrologic data used to complete the assessment include the following:

- the climate data used to develop the HSPF model were obtained from the Atmospheric Monitoring Division of Environment Canada (EC) and Alberta Environment and Sustainable Resources Development (AESRD);
- additional short-term climate data were obtained from the Aurora Climate Station C1, which is operated by RAM; and
- stream flow data required for the HSPF model validation study were obtained from RAM and the Water Survey Division of Environment Canada (WSC).

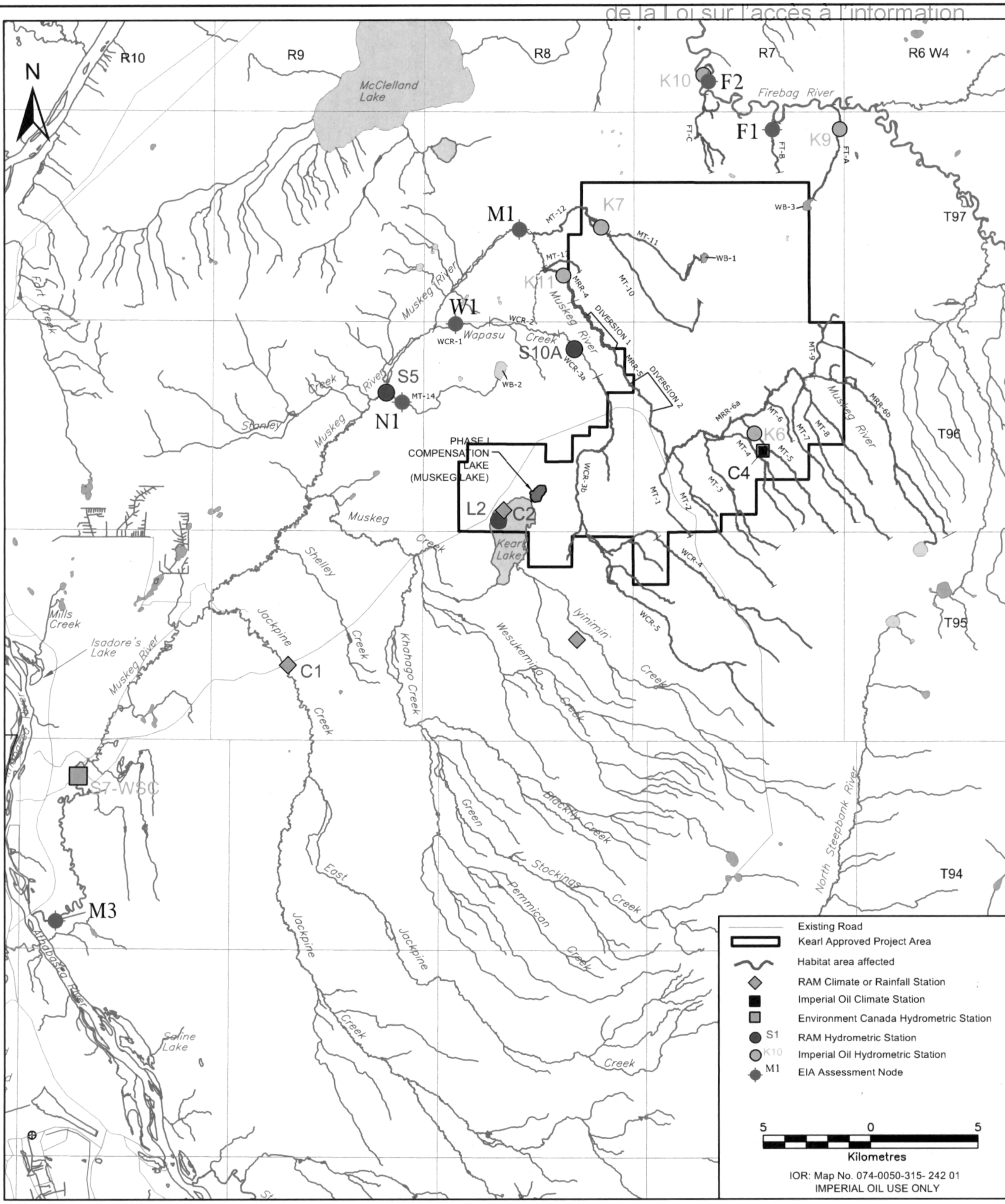
The Kearl EIA assessment nodes used for comparison against measured regional flow data include the following (Figure 3-20):

- Node M1: Muskeg River downstream of Kearl (relative to the Project Case for the Year 2007);
- Node M3: Muskeg River at the mouth (relative to the Potential Development Case for the Year 2007);
- Node W1: Wapasu Creek at the mouth (relative to Project Case for the Year 2007);
- Node K1: Kearl Lake (relative to Project Case for the Year 2007); and
- Node F2: Firebag River downstream of Kearl (relative to Project Case for the Year 2007).

074-0050-315- 242 01

AutoCAD

CADD DRAWING NO MANUAL CHANGES



Version: 3

A-PSTD

NOTES:

Imperial

IMPERIAL OIL RESOURCES

KEARL - MINING
ASSESSMENT NODES CONSIDERED FOR THE KEARL EIA
AQUATICS SITE LOCATIONS MAP

PROJECTION	DATUM	CONTRACTOR NAME	CONTRACTOR DRAWING NUMBER
UTM Z12	NAD83	GOLDER ASSOCIATES LTD.	FIGURE 3-20

DRAWN	CHECK	DESIGN	APPR.	DATE	SCALE	IOR DRAWING NUMBER	REV
RFM	JH	--	--	06 03 25	1:250,000	074-0050-315- 242 01	A

Filename: L:\IMPERIAL_OIL\KEARLMINING\18110265\02_PRODUCTION\100\DWG\18110265_100-HS-0002.DWG User ID: BMCDONALD Plot date/time: March 25, 2019 - 9:41am

3.5.2.2 *Trend Detection and Comparison to EIA Predictions*

To evaluate the potential impacts of Kearl development, hydrologic statistics from measured flows at regional stations were visually evaluated for trend and, where relevant, compared against statistics for modelled flows at the five Kearl EIA assessment nodes listed in the previous section. The statistics used in the comparison were as follows:

- mean annual discharge (or water level) - average, low, and high;
- mean open-water season (mid-April to mid-November) discharge (or water level) – average, low and high; and
- mean ice-cover season (mid-November to mid-April) discharge (or water level) – average, low and high.

The terms "average, low and high" in the list above refer to the following.

- Average: the long-term mean of the statistic, averaged over the 50 years of simulation (1954 to 2003) of the HSPF model.
- Low: the smallest value in the 50 individual years of simulation (e.g. for the open-water season mean, the smallest value in the fifty value time series of open-water season mean).
- High: the largest value in the 50 individual years of simulation.

Visual evaluations of potential trends in the annual flow series were used rather than statistical measures because of the relatively small number of data in each time series and the significant year-to-year scatter in the data. In such cases, the confidence limits on slope lines are too large to provide meaningful estimates of the "actual" trend.

Section 3.5.3 present the results of the flow assessment for each regional flow station listed in Table 3-13 relative to the five Kearl EIA assessment nodes. In some cases, there is a measured flow or water level station at or very near the assessment node. For some watercourses, however, the assessment node is located relatively far away. In such cases, annual measured data statistics are pro-rated based on drainage area to allow for comparison to the EIA prediction.

Some of the differences in annual mean discharge are attributed to the assumptions used during the Project EIA assessment regarding the schedule of Kearl, Aurora South Mine and Jackpine Mine Phase 1 as described in Section 3.5.1.

Table 3-13: Kearl or RAM Hydrometric Station Details Compared to Kearl EIA Assessment Nodes

Station Number	Station Name	Watershed Area (km^2)	Station Location (UTM Z12)	Period of Record
K10 (EIA node F2)	Firebag River downstream of Kearl	3,410	494947 E, 6371299 N	2007 - present
S10A (upstream of EIA Node W1)	Wapasu Creek downstream of Kearl	91.2 (106 at EIA node W1)	488573 E, 6358554 N	2001 - present
L2 (EIA Node K1)	Kearl Lake	92.2	484856 E, 6351061 N	1989 - 1990 and 1999 - present
S7 WSC (upstream of EIA node M3)	Muskeg River Mouth	1,283 (1,485 at EIA node M3)	465408 E, 6338944 N	1974 - present
S5 (downstream of EIA Node M1)	Muskeg River	410 (244 at EIA node M1)	479820 E, 6356551 N	2003 - present

Note: Kearl Station K11 is close to the EIA node M1 on the upper Muskeg River, however it does not include flows from an unnamed tributary northeast of the Muskeg River.

3.5.3 Evaluation Results

3.5.3.1 Annual Time Series

Firebag River Downstream of Kearl

The Kearl project was predicted to have negligible effects on the Firebag River at Node F2, and that station may therefore be used in as a reference for year-to-year natural variability.

The Firebag River is monitored at Kearl hydrology station K10 (drainage area 3,410 km^2). Kearl EIA predictions were provided at assessment node F2 (i.e., at the same location). A downstream gauge (RAM Station 27, drainage area 5,959 km^2) and upstream RAM hydrometric Station 43 above Suncor Firebag (drainage area 3,300 km^2) were used to derive a flow record for K10 for the period 1 March 2008 to 31 October 2018. The measured data had many gaps which were infilled by prorating the flows based on drainage areas from Station 43 as the first priority, and secondly at Station 27. The resulting measured and derived 11-year streamflow record for K10 is shown in Figure 3-21. A few gaps remain in the record over the winter of 2008 to 2009, winter of 2009 to 2010, and a few winter months in 2018 as none of the stations had data available for these periods.

Annual and monthly flow statistics from the 11-year flow record shown in Figure 3-21 are also summarized in Section 3.5.3.2 – Table 3-14. Annual mean, annual open-water mean, and annual ice-covered mean discharge values for Station K10 for 2008 to 2018 are shown in Figure 3-22. As shown in the figures, 2013 stands out as the highest flow year on record for the Firebag River at the mouth (RAM Station S27). The daily mean flood peak of 373 m^3/s that occurred 15 June 2013 was the highest on record since 1971 for the Firebag River Mouth. Flows on the Firebag River at all monitoring locations were relatively low in 2010 and 2011, and also between 2015 and 2017.

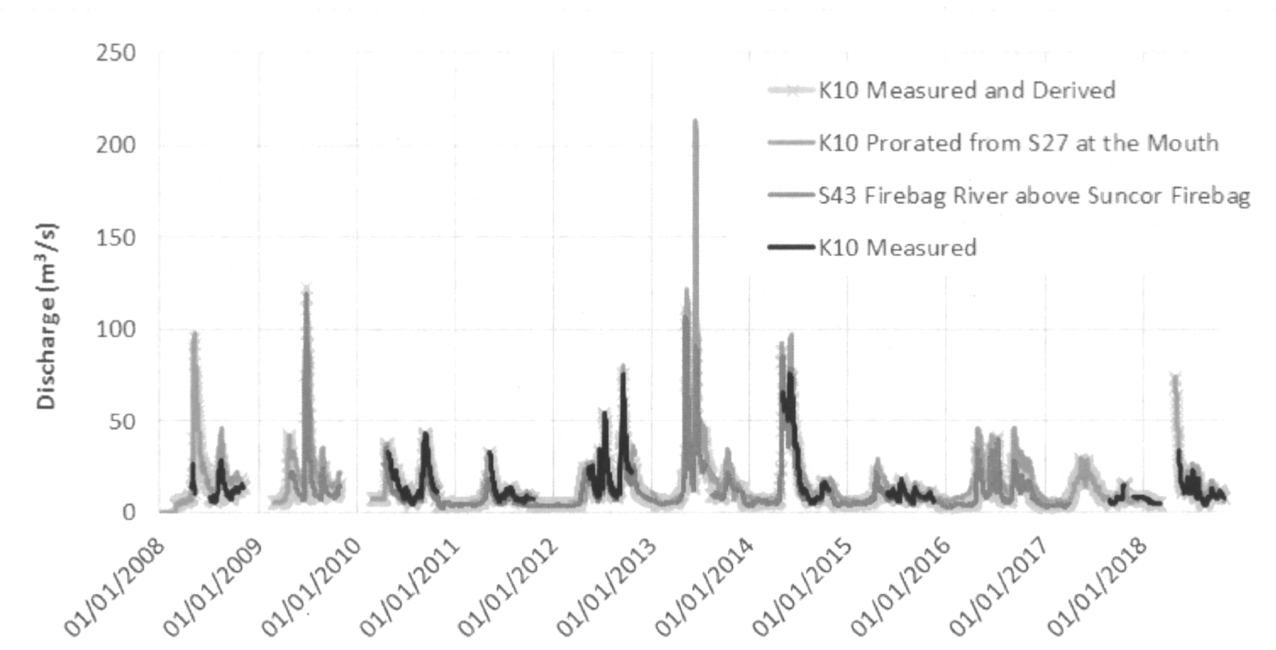


Figure 3-21: Measured Flows at Kearl Hydrology Station K10 on the Firebag River from 2008 to 2018 Compared to Flows at Station S43 and Pro-rated Flows from Station S27

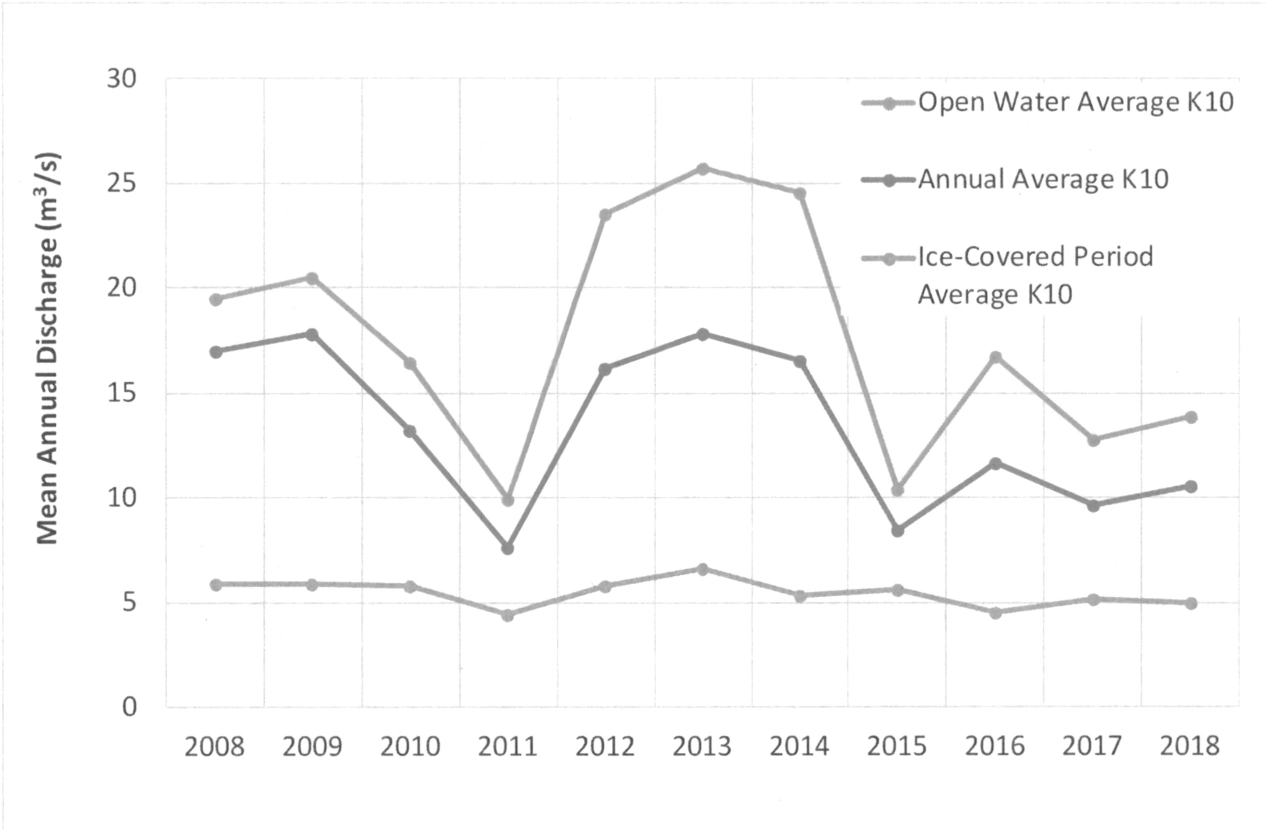


Figure 3-22: Measured and Derived Mean Annual and Seasonal Flows at Station K10 on the Firebag River, 2008 to 2018

Wapasu Creek Downstream of Kearl

The EIA did not predict any changes to Wapasu Creek at Node W1 due to the Project for the year 2007; although increased flows were predicted later during the period of operation (e.g., year 2044) due to muskeg drainage and overburden dewatering. To date, there are no changes to Wapasu Creek watershed. As no changes are expected at this time, only the measured data for a relatively new hydrometric station located near the mouth of Wapasu Creek is shown. The daily mean hydrograph for Station S10A is shown in Figure 3-23. Annual mean and seasonal mean flows for Station S10A are provided in Figure 3-24. As shown in the figures, 2013 stands out as the highest flow year on record for this station with a peak daily mean flow of just over 18 m^3/s on 16 June 2013. Flows were relatively low for 2015, 2016 and through to March 2017, even though local precipitation amounts for 2016 were above average at RAM Climate Station C1. Rainfall at Kearl Climate Station C4 in 2016 was close to average.

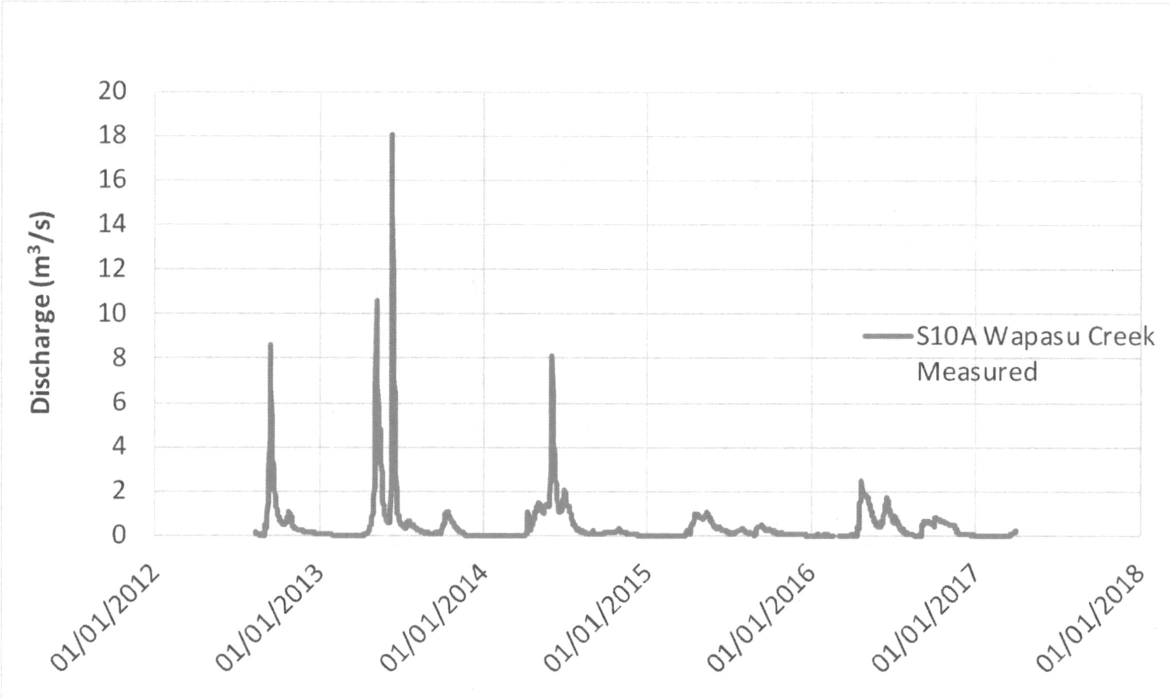


Figure 3-23: **Measured Mean Daily Flows at Station S10A on Wapasu Creek, August 2012 to March 2017**

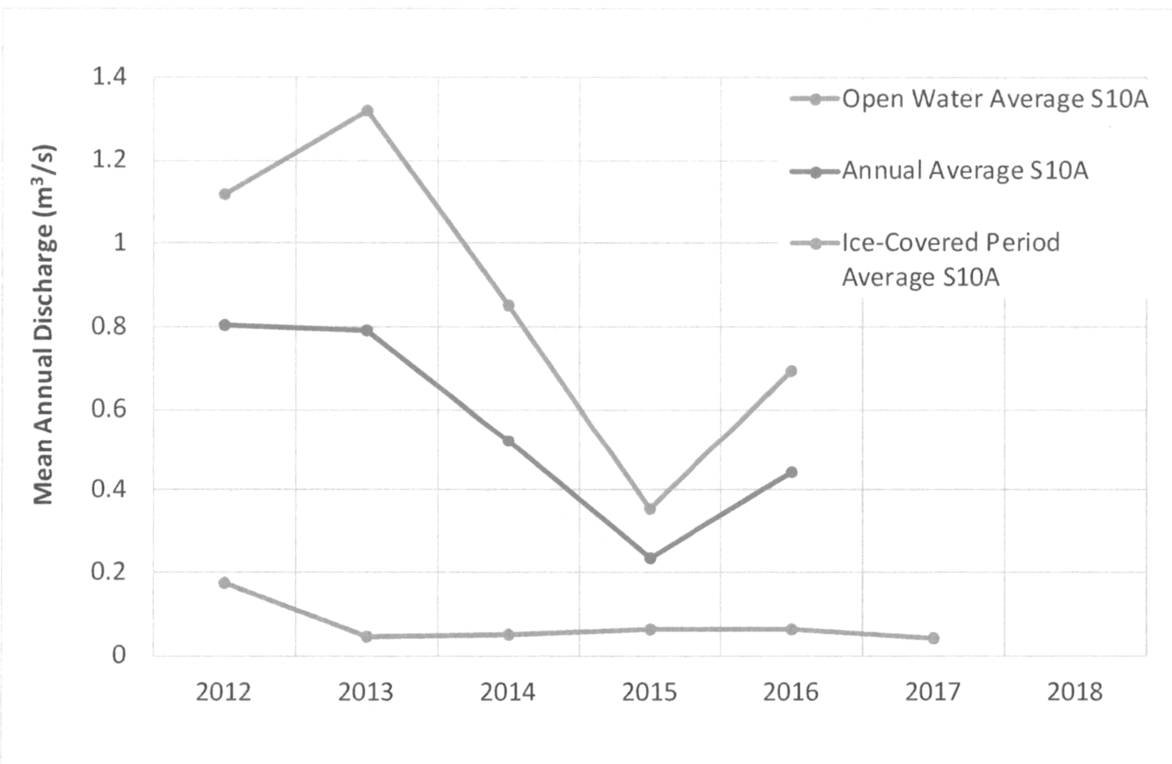


Figure 3-24: **Measured Mean Annual and Seasonal Flows at Station S10A on Wapasu Creek, August 2012 to March 2018**

Kearl Lake

Flows to Kearl Lake were not expected to be affected by the Kearl project. The lake is of interest primarily because Muskeg Lake (which has a much smaller surface area but is deeper than Kearl Lake) was constructed adjacent to the lake and the two waterbodies connected by a channel in 2014. Water was pumped from Kearl Lake to fill Muskeg Lake between 2010 and 2013. Given the relatively large size of the channel connecting Kearl and Muskeg lakes, it is expected that water levels in the two lakes are virtually identical. The surface area of Kearl Lake and Muskeg Lake combined is 0.3 km^2 larger than Kearl Lake alone, which is about a 7% increase in surface area (Imperial Oil 2007). The effect of changes in water balance were predicted to decrease Kearl Lake water levels by a few centimetres.

The daily mean water level records for Kearl Lake for RAM monitoring Station L2 are provided in Figure 3-25a. Water levels decreased somewhat between 2010 and 2013 but rebounded in subsequent years and appear to be stable and within the predicted mean annual values. In general, lake water levels were higher from 1999 to 2005 and appear to be lower thereafter. The pattern over time agrees fairly well with total precipitation for the hydrological years monitored nearby at RAM Climate Station C1; total precipitation was above average from 1999 to 2003, 2005, 2012 to 2014, and 2016.

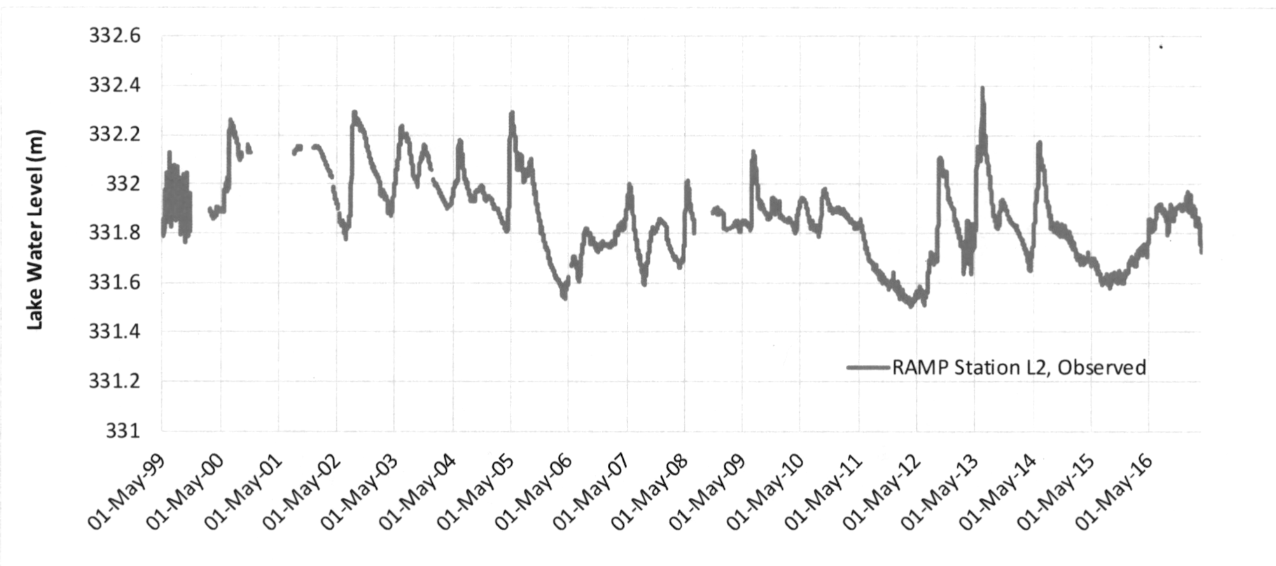


Figure 3-25a: Historical Daily Mean Water Levels at Kearl Lake Station L2 from May 1999 to March 2017

The EIA predicted mean annual and seasonal water levels for the year 2007 were close to the observed values (Figures 3-25b, c, d). [Note: due to an error in reporting geodetic elevations identified during Muskeg Lake construction, elevations were adjusted upward by 0.31 m to match datum recorded by RAM]. Mean annual observed water levels were 2 cm below the predicted value, mean annual open-water period water levels were 5 cm below the predicted value, and the mean annual ice-covered period water level was 3 cm above the predicted value. The maximum water level fluctuation for the period of record was 0.9 m, and the maximum fluctuation for the period since Muskeg Lake was connected to Kearl Lake (2014 to 2018) was about 0.6 m, within the 1 m range predicted in the NNLP.

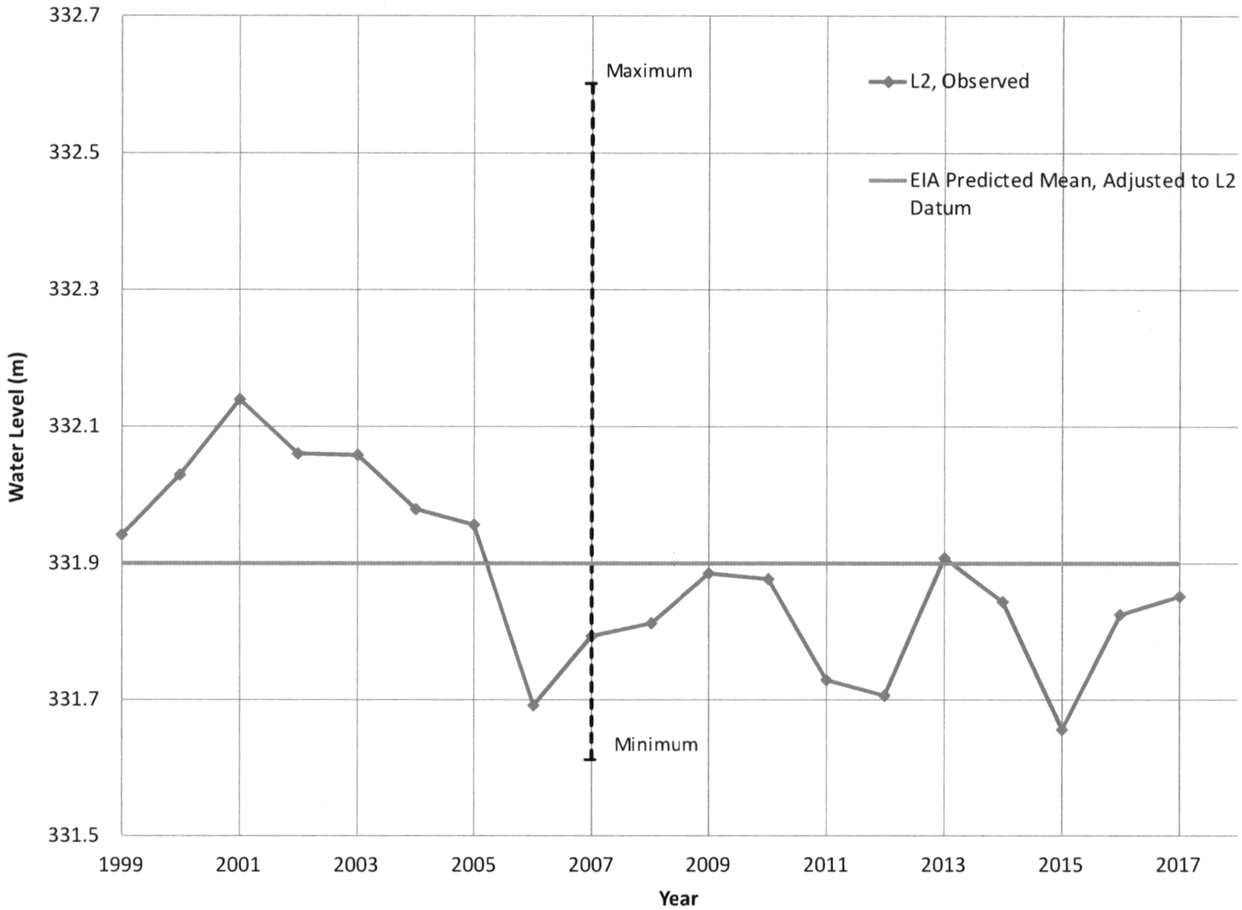


Figure 3-25b: **Comparison of Mean Annual Water Levels at Kearl Lake RAM Station L2 to EIA Predictions at Node K1**

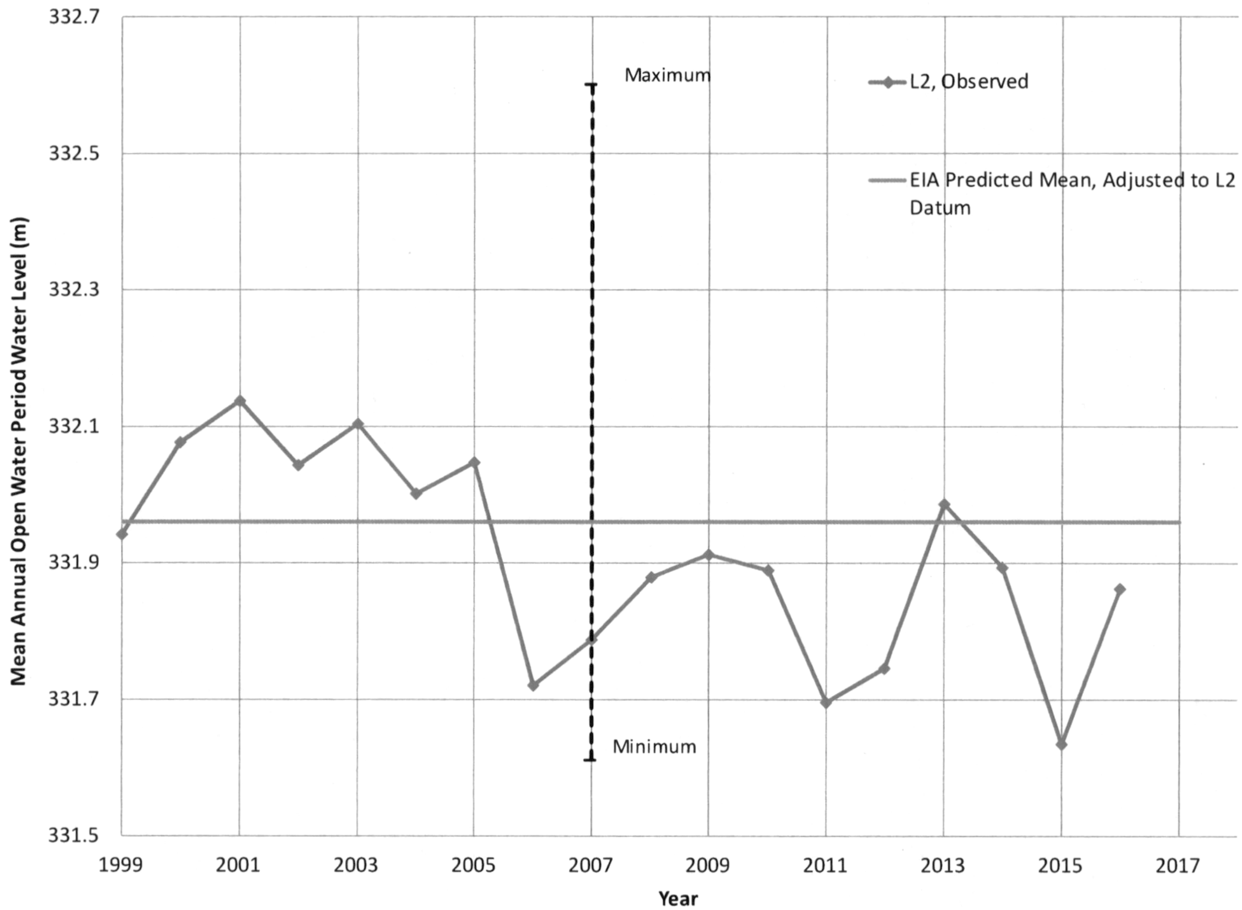


Figure 3-25c: **Comparison of Measured Open-Water Levels at RAM Station L2 (Kearl Lake) to EIA Predictions at Node K1**

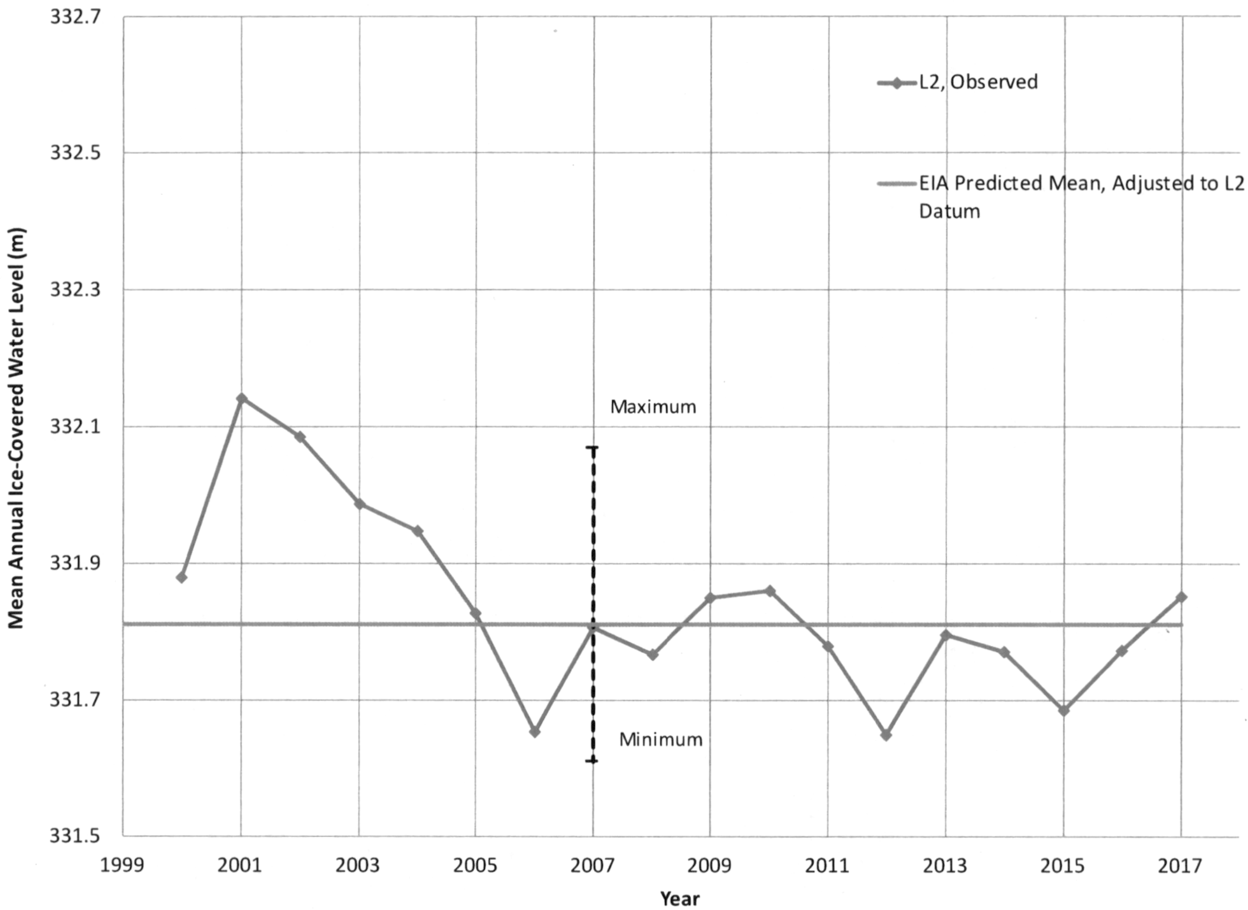


Figure 3-25d: Comparison of Measured Ice-Cover Water Levels at RAM Station L2 (Kearl Lake) to EIA Predictions at Node K1

Muskeg River Downstream of Kearl

EIA predictions for 2007 indicated that due to muskeg drainage and overburden dewatering, the mean annual flow would increase in the Muskeg River downstream of Kearl (EIA Node M1). Currently, no runoff has been released to this reach of the Muskeg River from overburden dewatering and the mine close-circuit area occupies a large part of this watershed, therefore the original predictions from the HSPF modelling may not be valid up to 2018.

The nearest monitoring station downstream with a long-term record is the Muskeg River above Stanley Creek at RAM Station S5, which is located further downstream and has a larger drainage area. The available records for Station S5 are shown in Figure 3-26a along with data for WSC Station S7 at the mouth of the Muskeg River.

Annual mean and seasonal mean flows at Station S5 from 1999 to 2017 are compared with the EIA predictions for Node M1 in Figures 3-26b, c and d. The mean annual flow at S5 for the period of record since 2003 is 1.13 m^3/s (Table 3-15) which is slightly lower than the predicted mean annual flow value of 1.2 m^3/s for 2007. The mean ice-covered flows have been decreasing slightly since 2003, although the mean open-water season flows and mean annual flows have been more stable. Some of the lower flow years are slightly less than the predicted minimum annual means during the open-water season. Peak daily mean flow of 14.8 m^3/s at S5 occurred 30 June 2009 and exceeded the 2013 flood event at this station. Floods exceeding a magnitude of 10 m^3/s have occurred five times since the record began in 2003 and the 2013 flood was not exceptional, which may be due to the increasing closed-circuit areas within the upper Muskeg River drainage.

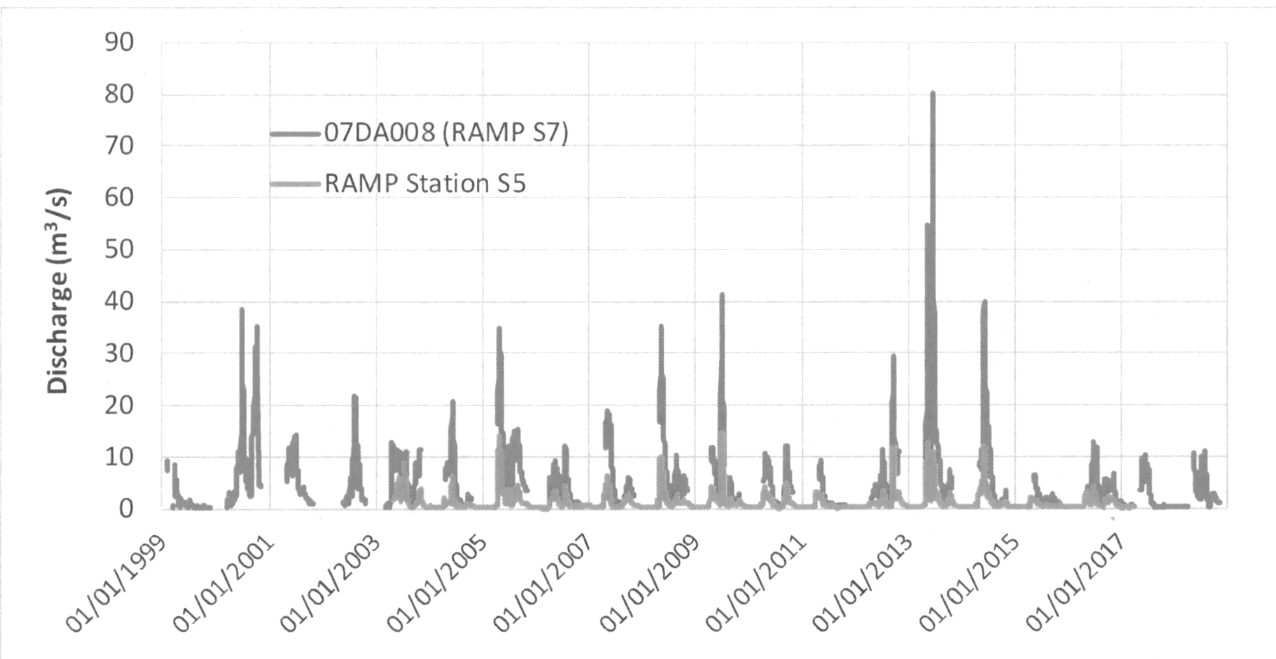


Figure 3-26a: Hydrographs for the Muskeg River at Stations S5 and S7

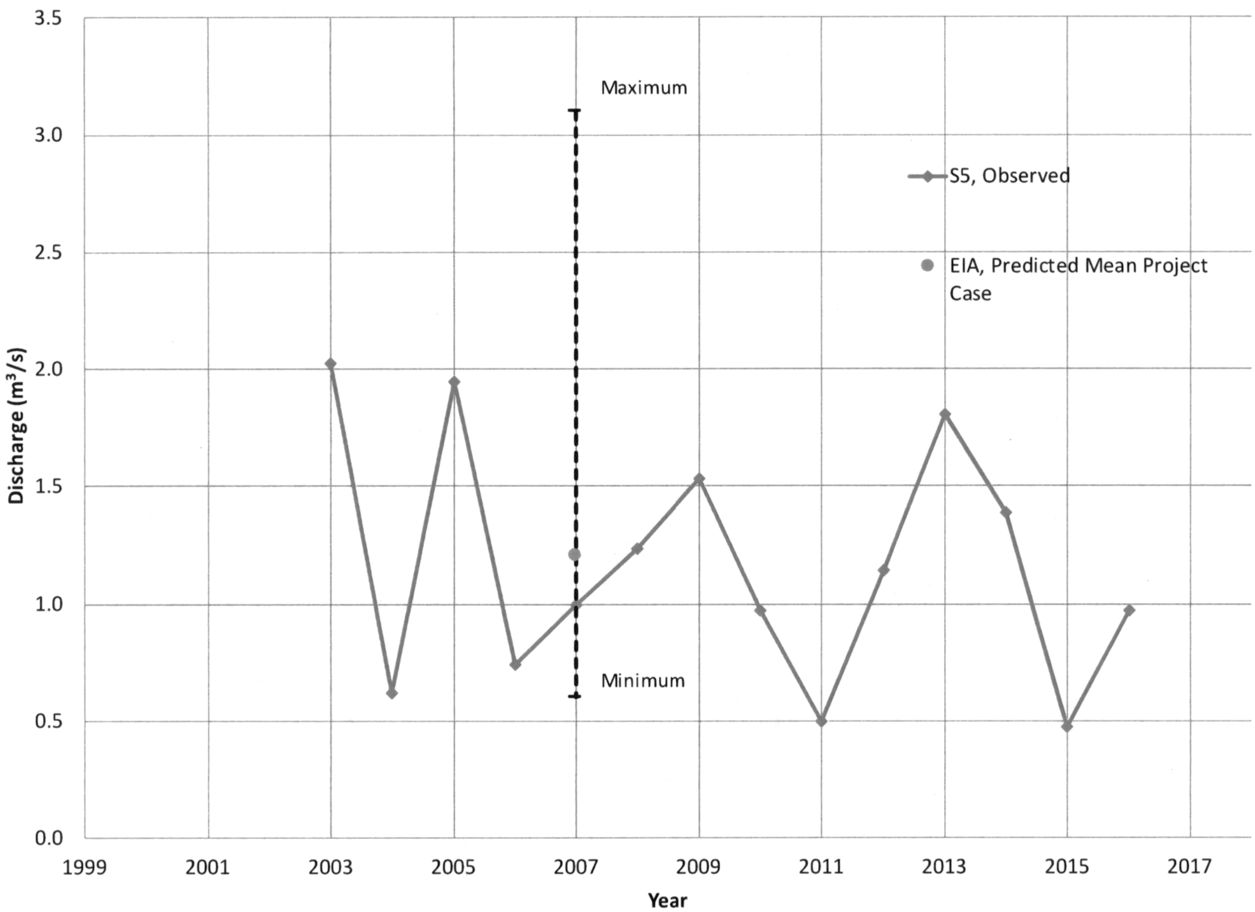


Figure 3-26b: Comparison of Measured Mean Annual Flows at RAM Station S5 to Flow Predictions at EIA Node M1

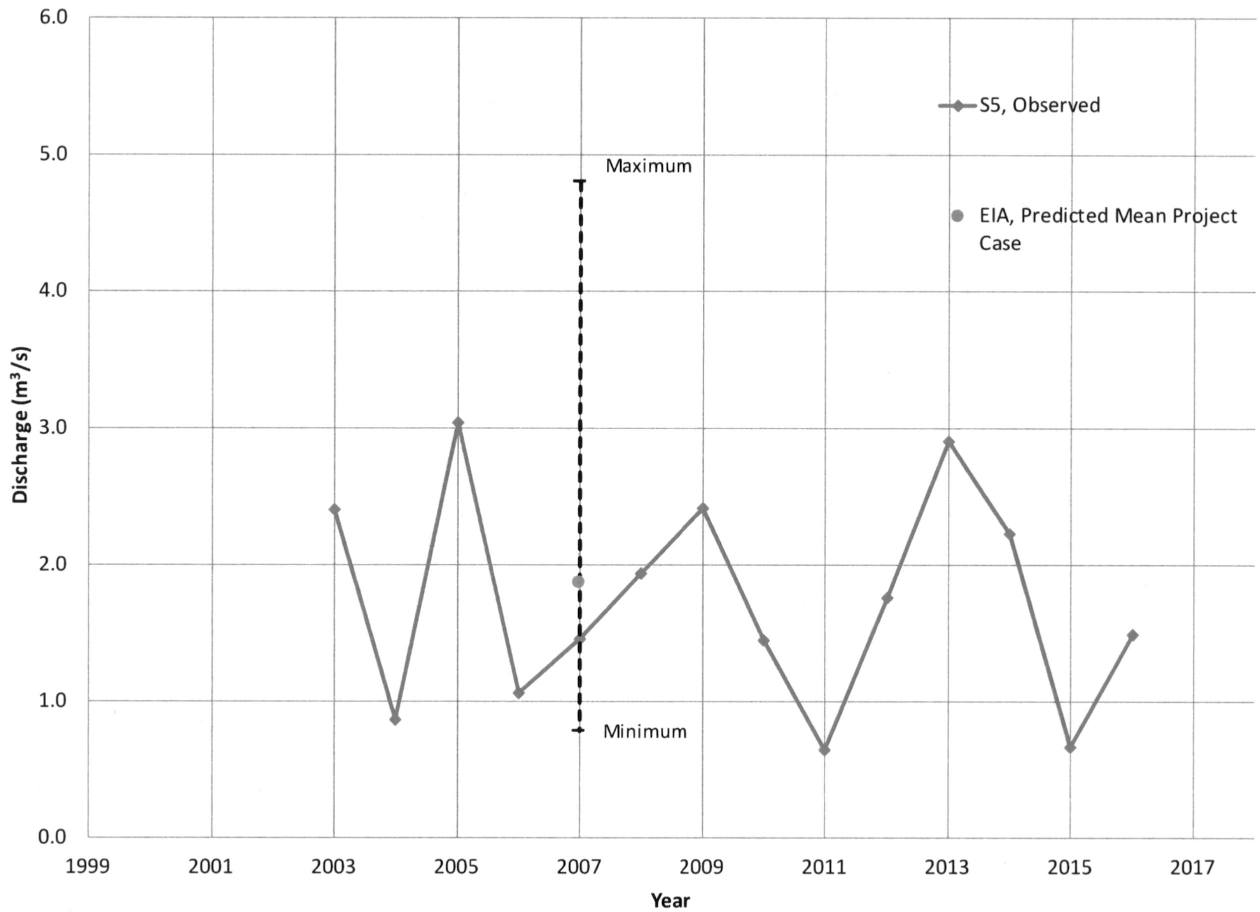


Figure 3-26c: Comparison of Measured Open-Water Flows at RAM Station S5 to Flow Predictions at EIA Node M1

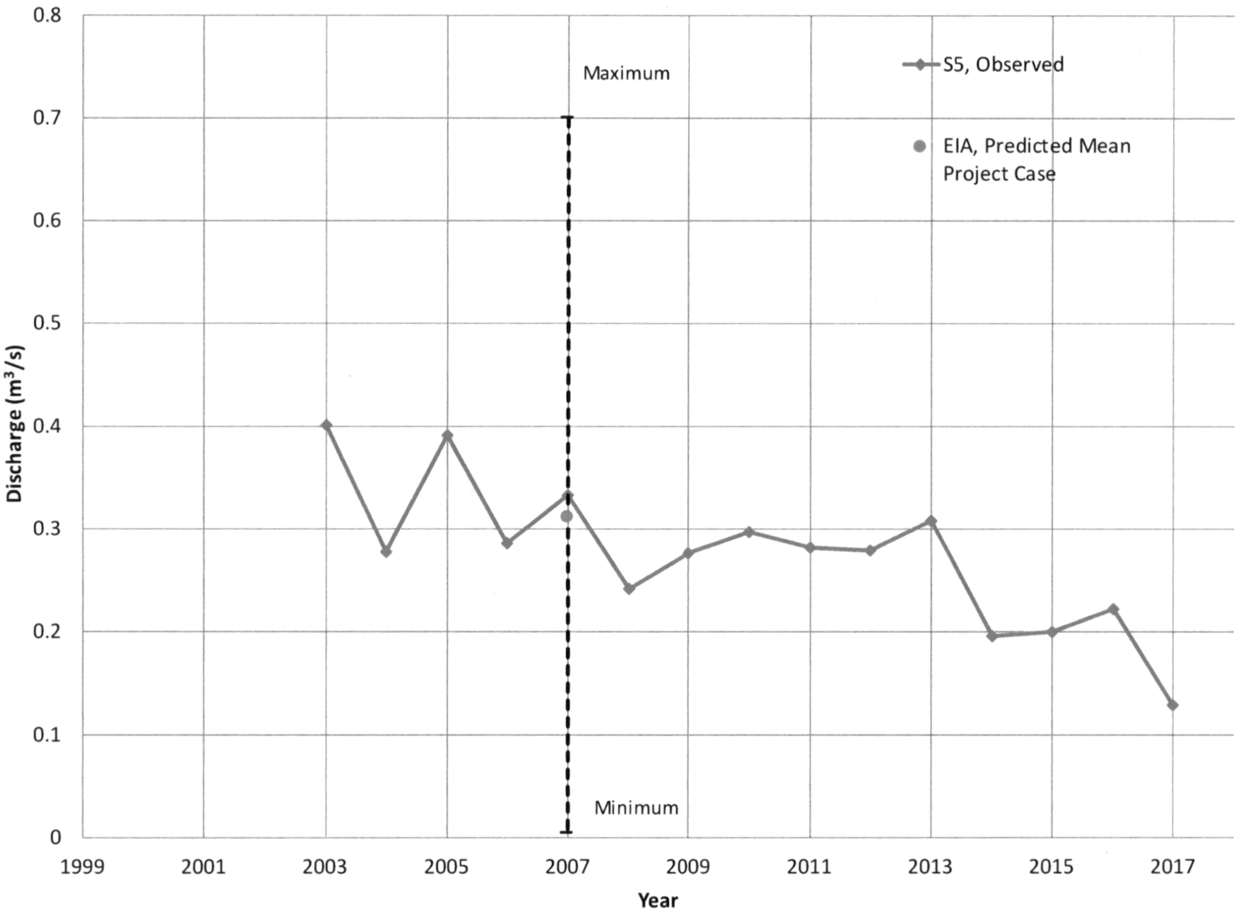


Figure 3-26d: Comparison of Measured Ice-Cover Flows at RAMP Station S5 to Flow Predictions at EIA Node M1

Muskeg River at the Mouth

EIA predictions for 2007 indicated that due to muskeg drainage and overburden dewatering, the mean annual flow would increase at the Muskeg River at the Mouth (EIA Node M3). The seasonal open-water period and ice-covered period flows were also predicted to increase. For Muskeg River at EIA Node M3 (Figure 3-27a, b and c) the EIA predictions are close to the average flows recorded by WSC at Station S7. The high flows in 2013 exceeded the predicted maximum annual values, and some of the lower flow years were less than the predicted range of flow values. The mean annual flow at S7 for the period of record since 1999 was 5.4 m^3/s (Table 3-15) which is slightly higher than the predicted mean annual flow value for 2007 based on the prediction of 4.9 m^3/s.

The hydrograph for the Muskeg River at Station S7 is shown in Figure 3-26a. The peak daily mean flow of 80.2 m^3/s occurred 15 June 2013 and this event was nearly twice that of any of the other flood events on record.

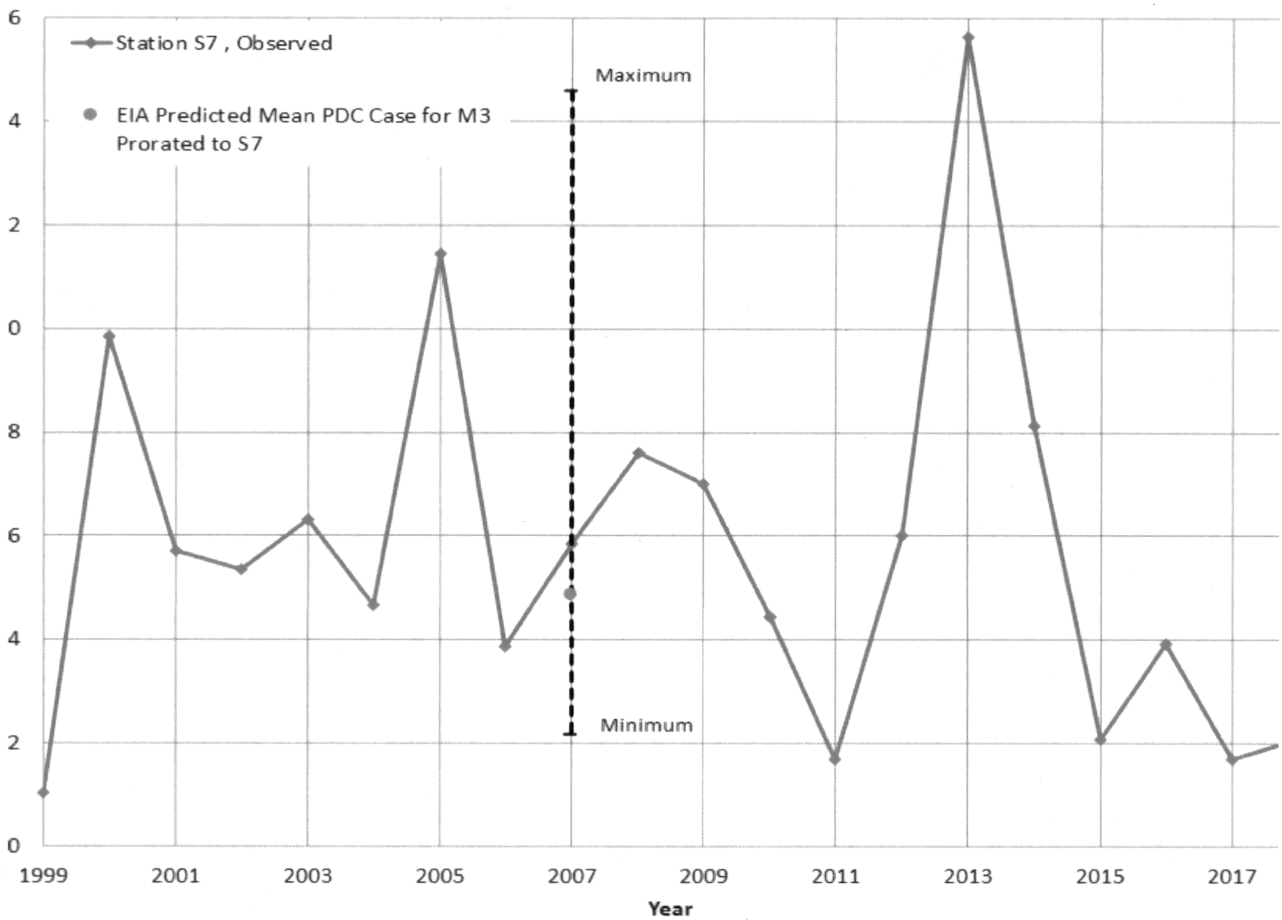


Figure 3-27a: Comparison of Measured Mean Annual Flows at WSC Station S7 to Flow Predictions at EIA Node M3

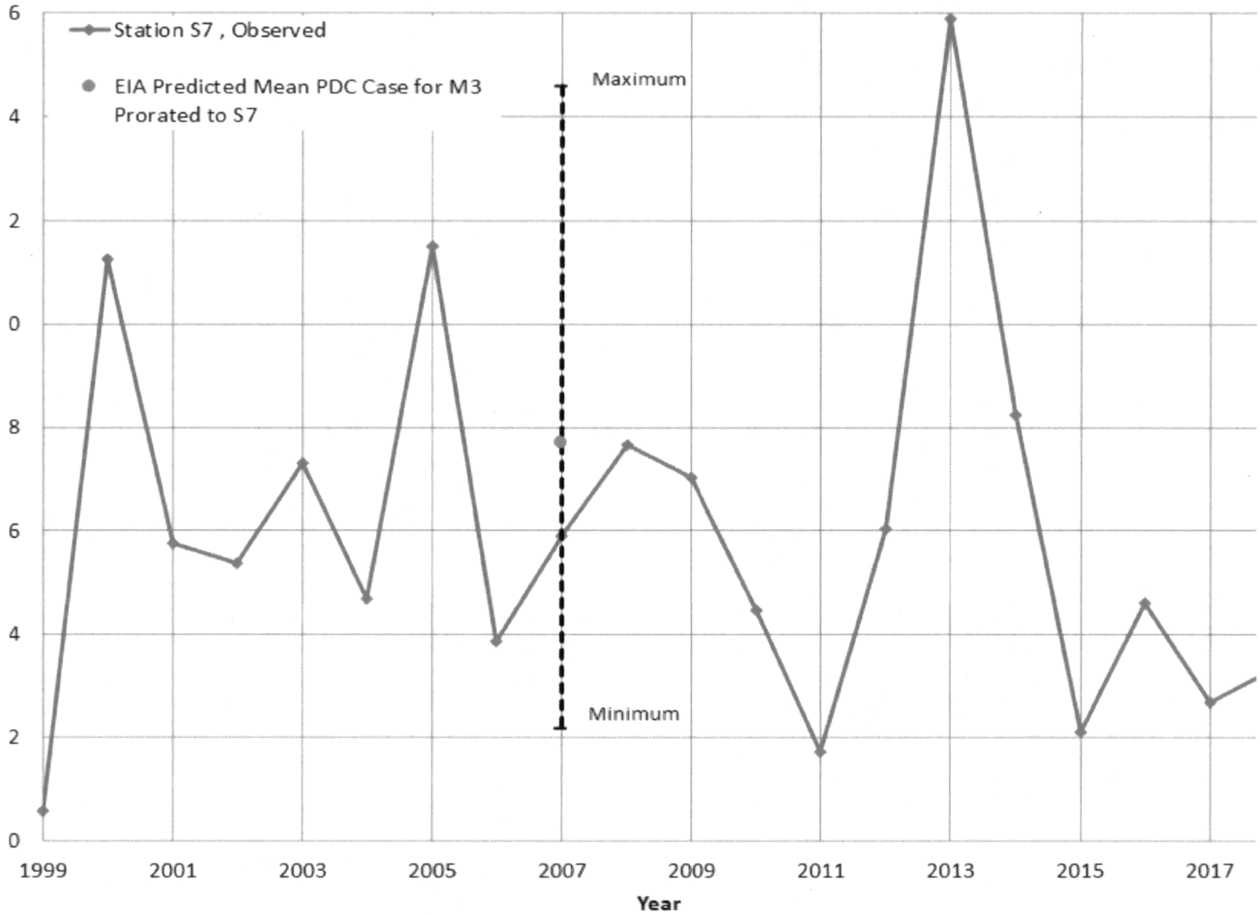


Figure 3-27b: Comparison of Measured Open Water Flows at WSC Station S7 to Flow Predictions at EIA Node M3

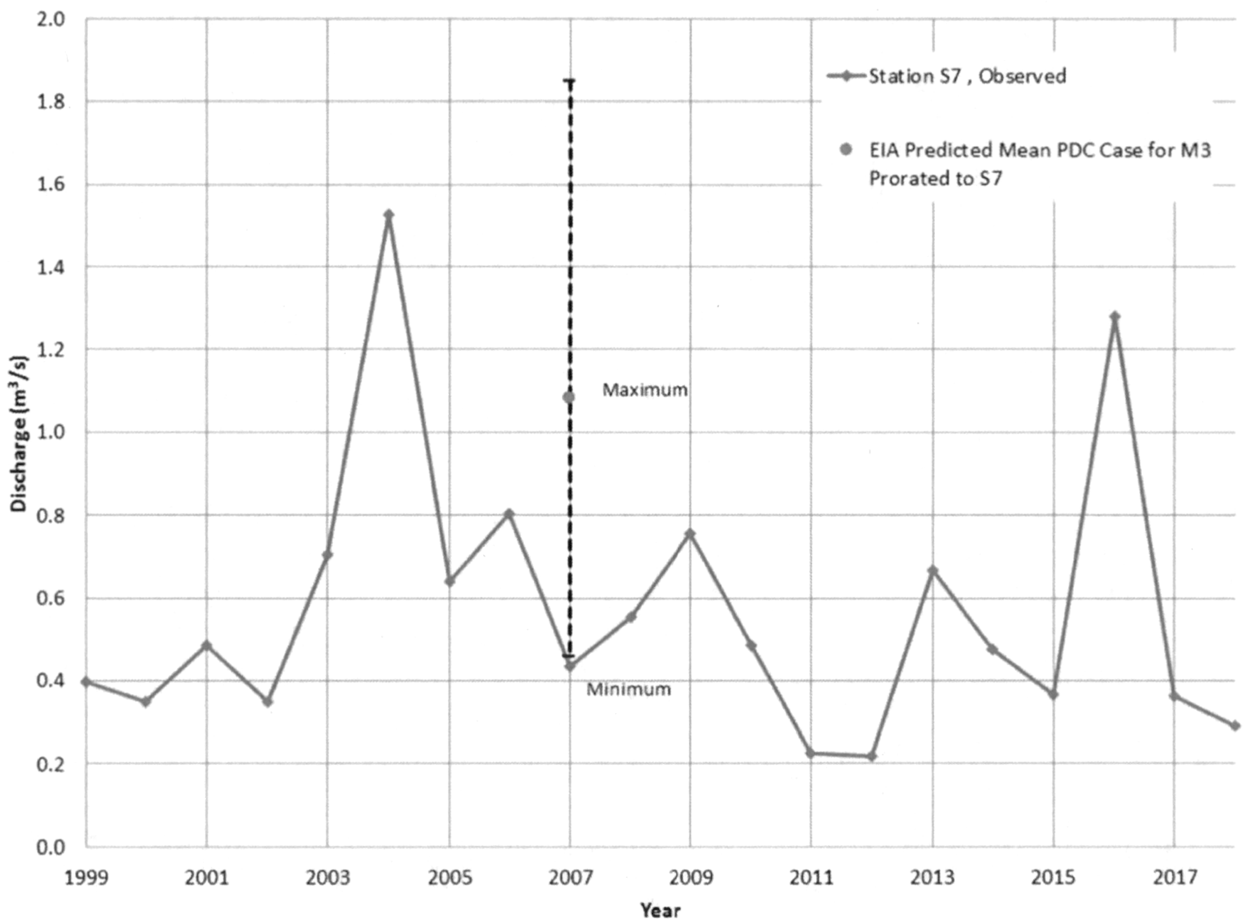


Figure 3-27c: Comparison of Measured Ice Cover Flows at WSC Station S7 to Flow Predictions at EIA Node M3

3.5.3.2 Summary of Long-Term Flow Statistics for RAM Hydrometric Stations

Long-term monthly and annual water level and discharge statistics of recorded flows at RAM hydrometric stations are provided in Tables 3-14 to 3-17 below.

Table 3-14: Mean Monthly Water Level or Discharge Statistics for Selected Hydrometric Stations

Flow or Water Level Statistics	Firebag River at K10 (EIA Node F2)	S10A Wapasu Creek (m^3/s) (EIA Node W1)	L2 Kearl Lake Water Levels (m) (EIA Node K1)	S5 Muskeg River Upper Reach (m^3/s) (EIA Node M1)	S7 Muskeg River at the Mouth (m^3/s) (EIA Node M3)
Period of Record	2008 to Present	2012 to Present	1999 to Present	2003 to Present	1999 to Present
January	4.623	0.029	331.174	0.207	0.409
February	4.763	0.023	331.082	0.158	0.627
March	5.144	0.037	331.156	0.162	0.804
April	12.451	0.582	330.416	1.796	7.297
May	29.779	1.719	329.945	3.242	9.764
June	23.104	1.954	331.271	2.168	8.644
July	17.894	0.506	331.911	1.779	6.221
August	10.086	0.130	331.263	0.721	3.306
September	15.336	0.726	331.900	1.317	4.187
October	13.071	0.495	331.220	1.120	3.903
November	7.942	0.194	331.149	0.630	1.170
December	5.320	0.066	331.859	0.274	0.542

Table 3-15: Mean Annual Water Levels and Flows at Selected Hydrometric Stations

Flow or Water Level Statistics	Firebag River at K10 (m^3/s) (EIA Node F2)	S10A Wapasu Creek (m^3/s) (EIA Node W1)	L2 Kearl Lake Water Levels (m)	S5 Muskeg River Upper Reach (m^3/s)	S7 Muskeg River at the Mouth (m^3/s)
1999	10.7	No data	331.941	No data	1.030
2000	20.3	No data	332.031	No data	9.868
2001	14.7	No data	332.140	No data	5.720
2002	20.7	No data	332.061	No data	5.357
2003	20.7	No data	332.059	2.023	6.306
2004	18.9	No data	331.979	0.623	4.676
2005	31.2	No data	331.957	1.946	11.453
2006	20.3	No data	331.692	0.745	3.858
2007	18.1	No data	331.795	0.995	5.856
2008	17.0	No data	331.813	1.234	7.614
2009	17.8	No data	331.887	1.535	6.992
2010	13.3	No data	331.878	0.973	4.444
2011	7.7	No data	331.730	0.499	1.707
2012	16.1	0.802	331.707	1.144	6.008
2013	17.8	0.790	331.908	1.804	15.659
2014	16.6	0.519	331.844	1.389	8.122
2015	8.4	0.233	331.657	0.475	2.082
2016	11.6	0.445	331.825	0.975	3.928
2017	9.6	0.042	331.852	0.130	1.707
2018	10.6	No data	No data	No data	2.070
Mean Annual	13.3	0.498	331.866	1.129	5.412

Note: K10 data prior to 2008 was entirely derived by pro-rating flows from the Firebag River at the Mouth

Table 3-16: Mean Annual Open Water Period (15 April to 15 November) Water Levels and Flows at Selected Hydrometric Stations

Flow or Water Level Statistics	Firebag River at K10 (EIA Node F2)	S10A Wapasu Creek (m^3/s) (EIA Node W1)	L2 Kearl Lake Water Levels (m)	S5 Muskeg River Upper Reach (m^3/s)	S7 Muskeg River at the Mouth (m^3/s)
1999	11.8	No data	331.941	No data	0.580
2000	23.1	No data	332.078	No data	11.263
2001	16.8	No data	332.138	No data	5.750
2002	24.1	No data	332.044	No data	5.389
2003	24.4	No data	332.104	2.413	7.313
2004	21.4	No data	332.002	0.868	4.699
2005	36.9	No data	332.049	3.043	11.509
2006	22.9	No data	331.721	1.068	3.879
2007	21.1	No data	331.788	1.462	5.886
2008	19.5	No data	331.879	1.939	7.653
2009	20.5	No data	331.913	2.424	7.026
2010	16.5	No data	331.890	1.449	4.465
2011	9.9	No data	331.695	0.653	1.715
2012	23.5	1.116	331.746	1.758	6.039
2013	25.7	1.317	331.988	2.905	15.904
2014	24.5	0.853	331.895	2.235	8.245
2015	10.4	0.353	331.637	0.669	2.113
2016	16.7	0.694	331.863	1.493	4.614
2017	12.8	No data	No data	No data	2.677
2018	13.9	No data	No data	No data	3.347
Mean Open-Water Season (April 15 to Nov 14)	17.6	0.835	331.897	1.733	6.033

Note: K10 data prior to 2008 was entirely derived by pro-rating flows from the Firebag River at the Mouth

Table 3-17: Mean Annual Ice-Covered Period (15 November to 14 April) Water Levels and Discharge for Selected Stations

Flow or Water Level Statistics	Firebag River at K10 (EIA Node F2)	S10A Wapasu Creek (m^3/s) (EIA Node W1)	L2 Kearl Lake Water Levels (m)	S5 Muskeg River Upper Reach (m^3/s)	S7 Muskeg River at the Mouth (m^3/s)
1999	5.8	No data	No data	No data	3.720
2000	8.0	No data	331.880	No data	1.412
2001	5.7	No data	332.143	No data	0.436
2002	5.8	No data	332.086	No data	0.195
2003	4.7	No data	331.988	0.402	1.273
2004	7.7	No data	331.948	0.278	0.435
2005	6.1	No data	331.828	0.393	0.476
2006	8.9	No data	331.655	0.287	3.602
2007	5.2	No data	331.807	0.333	0.245
2008	5.84	No data	331.768	0.242	0.385
2009	5.85	No data	331.850	0.277	0.305
2010	5.78	No data	331.861	0.298	0.485
2011	4.5	No data	331.780	0.282	0.225
2012	5.8	0.175	331.651	0.280	0.219
2013	6.6	0.043	331.795	0.308	0.668
2014	5.3	0.049	331.771	0.196	0.475
2015	5.6	0.062	331.686	0.200	0.365
2016	4.5	0.064	331.773	0.222	1.280
2017	5.2	0.042	331.852	0.130	0.362
2018	4.9	No data	No data	No data	0.290
Mean Ice-Covered Season (Nov 15 to Apr 14)	5.4	0.061	331.821	0.273	25.4

Note: K10 data prior to 2008 was entirely derived by pro-rating flows from the Firebag River at the Mouth

3.5.4 Evaluation Conclusions

To evaluate the hydrology model predictions from the Kearl EIA Application Case, the predictions were compared with recorded monitoring data. The range of variability of flows and water levels recorded by Kearl and regional hydrometric stations are generally within the predicted flow and water level statistics provided in the Kearl EIA application, with occasional exceptions. The flood event in the area that occurred in June 2013 caused several local stations to have record high flows. Low flows have occurred at most Kearl and regional hydrometric stations from 2015 to 2017.

For EIA predictions for Kearl Lake (Node K1), the data indicates that the average annual lake levels up to 2005 were generally higher than they have been thereafter. This does not seem to be related to the filling of Muskeg Lake from 2010 to 2013 but is likely due to higher than average precipitation from 1999 to 2003 and in 2005 (as measured at RAM Climate Station C1). In addition, the filling protocol for Muskeg Lake limited the volume of water transferred from Kearl Lake so as to remain in compliance with the Muskeg River Interim Management Framework for Water Quantity and Quality (Alberta Environment 2008) to mitigate effects on Kearl Lake water levels. Lake levels at Kearl should continue to be monitored each year to verify lake levels remain stable in a range of natural hydrological conditions that may occur.

For Muskeg River downstream of Kearl (Node M1 - as measured by RAM Station S5 above Stanley Creek) the mean ice-covered flows have been decreasing since 2012, although the mean open-water season flows and mean annual flows have been more stable. This watershed has increasing closed-circuit areas within it, and no overburden dewatering has occurred to date, which may explain why flows have not increased as originally predicted in the Kearl EIA. It is possible that the large flood in June 2013 was partially attenuated in this watershed as it was not a record high event at Station S5.

For Muskeg River at the mouth (Node M3), the seasonal open-water period and ice-covered period flows were predicted to increase for the year 2007. The EIA predictions are close to the average flows recorded by WSC at Station S7. The high flows in 2013 exceeded the predicted maximum annual values, and some of the lower flow years are less than the predicted range of flow values. Some of the differences between the results of model predictions and the monitoring data are attributed to the difference in the assumptions used during the Project EIA assessment regarding the schedule of Kearl, Aurora South and Jackpine Phase 1 projects, as described in Section 3.4.1.

4.0 WATER AND SEDIMENT QUALITY PROGRAM

4.1 Water and Sediment Quality Monitoring Program Overview

The water and sediment quality component for the 2018 monitoring program consisted of water and sediment sample collection and analysis for Kearl monitoring stations, as described in the SWFM Plan (Imperial Oil 2009a), as well as sampling at additional water quality monitoring stations that were previously sampled as part of regional monitoring programs (RAM), but where regional sampling activities were recently reduced. In total, the planned 2018 program included water quality monitoring at six watercourse stations and two waterbody stations (Figure 2-1), as follows:

- three stations operated by Imperial (watercourse Stations FR-1, MR-2, and waterbody Station NNL-1);
- four stations operated under RAM where Imperial provided supplemental seasonal sampling (watercourse Stations IYC-1, MUR-6, WAC-1, and waterbody Station KEL-1); and
- one station formerly operated by AEP where Imperial conducted seasonal water quality sampling (watercourse Station AB07DA0440).

The planned 2018 program also included sediment quality monitoring at five of these stations: watercourse Stations FR-1, WAC-1 and AB07DA0440, and waterbody Stations NNL-1 and KEL-1.

Monitoring at Imperial Station FR-1 in the Firebag River was a continuation of the combined baseline data collection and monitoring programs that took place from 2006 through 2017. Monitoring of Station MR-2 in the Muskeg River was added at the start of the long-term monitoring program in 2009 to establish a water quality monitoring station in the Kearl air emissions pathway, and monitoring in Muskeg Lake (Station NNL-1) was a continuation of monitoring that was initiated in 2012, as the newly constructed lake basin was being filled.

Sampling at Station KEL-1 and an increased frequency of sampling at Station IYC-1 were added to the program in 2014, as a result of RAM reducing the frequency of sampling at these stations to fall only. The increased sampling consisted of adding sampling at Station KEL-1 in the winter and at Station IYC-1 during the spring and summer. Water quality monitoring at Station AB07DA0440 was also added in all seasons due to AEP no longer sampling at this location.

In 2018, the frequency of sampling at Stations KEL-1, IYC-1, MUR-6 and WAC-1 further increased relative to previous monitoring years as a result of RAM reducing the frequency of sampling at these stations. The increased sampling at Station KEL-1 consisted of adding sediment sampling in the summer program and the increased sampling at Stations IYC-1, MUR-6 and WAC-1 consisted of the addition of water quality sampling during the fall. In addition, RAM discontinued sampling at the regional monitoring station on Muskeg Creek (i.e., Station MUC-1) and consideration was given to adding MUC-1 sampling to the Imperial monitoring program. However, sampling at Station MUC-1 could not be completed in 2018 due to access limitations (the station is located on private property) and it was subsequently removed from consideration.

The winter and fall portions of the 2018 water quality monitoring program consisted of sample collection from all eight of the planned monitoring stations in conjunction with the hydrology survey. During the spring and summer portions of the 2018 monitoring program, the water quality sampling was split into two programs: the watercourse monitoring stations were sampled in conjunction with the hydrology surveys, and the waterbody monitoring stations were sampled in conjunction with the fisheries surveys. All eight stations were sampled as planned in spring and summer, with the exception of Stations IYC-1 and FR-1 in the summer program – these locations were not sampled due to weather and were instead sampled later in conjunction with the late summer fisheries survey.

For the 2018 monitoring program, sediment quality samples were collected at both waterbody stations in the late summer and from three watercourse stations during the fall (Tables 4-1 and 4-2); sediment toxicity samples were collected from two watercourse stations in fall.

Seasonal sampling dates for the 2018 monitoring program were as follows:

- winter – 6 to 10 March;
- spring – 14 to 15 May (watercourse monitoring stations) and 28 May (waterbody monitoring stations);
- summer – 21 August to 5 September (watercourse monitoring stations) and 2 September (waterbody monitoring stations); and
- fall – 15 to 18 October.

Table 4-1: Water and Sediment Quality Stations Sampled and Parameters Analyzed from Watercourse Stations, 2018

Watercourse	Watercourse Segment	Station ID	UTM Coordinates		Completed Monitoring Activities			
			Easting	Northing	Winter	Spring	Summer	Fall
Firebag River	Downstream of Kearl Area	FR-1	494671	6370832	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters) and Sediment quality[a] (RAM standard parameters)
Muskeg River	Reach MRR-6a	MR-2	497363	6339191	Water quality (RAM standard parameters)	Water quality (RAM standard parameters) and duplicate sample	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)
	Reach MRR-5	MUR-6	492174	6355472	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)
	Downstream of Kearl Area	AB07DA0440	486719	6363791	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters) and Sediment quality (RAM standard parameters and toxicity tests)
Wapasu Creek	Reach WCR-3b	WAC-1	490339	6355704	Water quality (RAM standard parameters) and duplicate sample	Water quality (RAM standard parameters)	Water quality (RAM standard parameters) and duplicate sample	Water quality (RAM standard parameters), duplicate sample, field blank, and Sediment quality (RAM standard parameters and toxicity tests)
Iyinimin Creek	Above Kearl Lake	IYC-1	489482	6344768	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)

Note: See Figure 2-1 for station locations; UTM = Universal Transverse Mercator Coordinates, North American Datum (NAD) 1983, Zone 12; RAM standard parameters are listed in the long-term SWFM Plan (Imperial Oil 2009a) as RAMP standard parameters; RAM = Regional Aquatics Monitoring.

[a] Sediment was limited at Station FR-1, so methanol vials for the BTEX/F1 analysis and planned toxicity samples could not be collected.

Table 4-2: Water and Sediment Quality Samples Collected and Parameters Analyzed from Waterbody Stations, 2018

Waterbody	Station ID	UTM Coordinates		Monitoring Activities			
		Easting	Northing	Winter	Spring	Late Summer	Fall
Muskeg Lake	NNL-1	486900	6351832	Water quality (RAM standard parameters), PAH/PANH, and field blank	Water quality (RAM standard parameters), PAH/PANH, and field blank	Water quality (RAM standard parameters), PAH/PANH, field blank, Sediment quality (RAM standard parameters), and sediment split sample	-
Kearl Lake	KEL-1	485658	6349916	Water quality (RAM standard parameters)	Water quality (RAM standard parameters)	Water quality (RAM standard parameters) and Sediment quality (RAM standard parameters)	-

Note: See Figure 2-1 for station location; UTM = Universal Transverse Mercator Coordinates, North American Datum (NAD) 1983, Zone 12; RAM standard parameters are listed in the long-term monitoring plan (Imperial Oil 2009a) as RAMP standard parameters; RAM = Regional Aquatics Monitoring; - = no sample collection was scheduled; PAH/PANH = target polycyclic aromatic hydrocarbons (PAHs), alkylated PAHs, and polycyclic aromatic nitrogen heterocycles (PANHs).

4.2 Monitoring Methods

4.2.1 Sampling Methods and Analytical Parameters

Water quality samples were collected from the six watercourse and two waterbody monitoring stations and analyzed for chemistry and toxicity, as described in Tables 4-1 and 4-2. At each watercourse station, sample bottles were filled by collecting grab samples from just below the surface at mid-channel. At each waterbody station, a composite water sample was prepared by mixing grab samples from three (winter) or four (open-water seasons) locations within each waterbody; efforts were made to sample at historical sampling locations in each waterbody. Sample bottles were then filled from the composite sample. Water quality field parameters were measured in-situ at each station and location where grab samples were collected, and consisted of measurements of water temperature, pH, specific conductivity and dissolved oxygen concentration. In-situ water quality measurements were made using a YSI Model 556 multimeter.

Sediment quality samples were collected from five monitoring stations, consisting of three watercourse stations and two waterbody stations (Tables 4-1 and 4-2), and all samples were analyzed for chemistry. Sediment samples from the three watercourse stations located downstream of the Kearl area (Stations FR-1, AB07DA0440 and WAC-1) were also to be analyzed for toxicity. However, toxicity samples could only be collected from two of these stations (FR-1 and AB07DA0440) due to the limited amount of sediment present at Station FR-1.

For chemical analysis, one composite sediment sample was prepared at each monitoring station by mixing five sediment grabs collected using an Ekman grab, and filling sample jars from the composite sample. Due to updated AEP/Canadian Council of Ministers of the Environment (CCME) analysis requirements, an additional sampling and preservation procedure for the analysis of F1/BTEX in sediment using methanol vials was introduced for the fall 2017 program. During the summer 2018 program, it was determined that using this method for collecting lake sediment was not effective because of the watery consistency of the sediment, and so the previous method of analysing from 125 mL soil jars was used. For the subsequent fall program, the two methods for collecting sediment for F1/BTEX analysis (i.e., F1/BTEX collected in methanol vials and F1/BTEX collected in soil jars) were both used to avoid the issues encountered in the summer program, and to allow for comparison between the methods. There was limited sediment availability at Station FR-1 in the fall program, so only the soil jar sampling method was used for F1/BTEX. For toxicity analysis at the watercourse monitoring Station WAC-1, five separate sediment samples were prepared by collecting five discrete grabs using an Ekman grab. Only three sediment samples were collected at Station AB07DA0440 due to limited sediment availability; the laboratory removed the required sediment from each sample to run the toxicity analyses and the volume of sediment that remained was then combined to create an additional two samples, for a total of five samples.

Water and sediment samples were shipped to Maxxam Analytics, Calgary, AB, for analysis of chemistry and toxicity parameters (Table 4-3), with some exceptions: total and dissolved mercury analyses were subcontracted by Maxxam to InnoTech Alberta (formerly Alberta Innovates – Technology Futures) in Vegreville, AB, and methyl mercury analysis was subcontracted to Flett Research in Winnipeg, MB.

Analytical results for the 2018 water and sediment quality samples are presented in this report, as are the water quality and sediment quality test results for samples collected during the fall 2017 sampling program that were not available at the time of preparing the 2017 Annual Monitoring Report.

Table 4-3: Water and Sediment Quality Parameters Analyzed in Samples Collected in 2018

Group of Parameters	Parameters[a]
Water Samples	
Field Measured	pH, specific conductivity, water temperature and dissolved oxygen (DO)
Conventional Parameters	Colour, specific conductivity, dissolved organic carbon (DOC), hardness, pH, total alkalinity, total dissolved solids (TDS), total organic carbon (TOC) and total suspended solids (TSS)
Major Ions	Bicarbonate, calcium, carbonate, chloride, magnesium, potassium, sodium, sulphate and sulphide
Nutrients	Nitrate, nitrate + nitrite, nitrite, ammonia, total Kjeldahl nitrogen (TKN), calculated total nitrogen (TN), total phosphorus (TP), dissolved phosphorus and biochemical oxygen demand (BOD)
Organics	Naphthenic acids, phenols and total recoverable hydrocarbons
Metals (Total and Dissolved)	Aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, methyl mercury[b], molybdenum, nickel, selenium, silver, strontium, thallium, titanium, uranium, vanadium and zinc
Target Polycyclic Aromatic Hydrocarbons (PAHs) and Alkylated PAHs[c]	Acenaphthene, C1 substituted acenaphthene, acenaphthylene, anthracene, dibenz(a,h)anthracene, benzo(a)anthracene, benzo(c)phenanthrene, C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene, C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene, biphenyl, C1 substituted biphenyl, C2 substituted biphenyl, chrysene, C1 substituted benzo(a)anthracene/chrysene, C2 substituted benzo(a)anthracene/chrysene, C3 substituted benzo(a)anthracene/chrysene, C4 substituted benzo(a)anthracene/chrysene, dibenzothiophene, C1 substituted dibenzothiophene, C2 substituted dibenzothiophene, C3 substituted dibenzothiophene, C4 substituted dibenzothiophene, fluoranthene, benzo(b&j)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)fluoranthene, fluorene, C1 substituted fluorene, C2 substituted fluorene, C3 substituted fluorene, naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, C1 substituted naphthalene, C2 substituted naphthalene, C3 substituted naphthalene, C4 substituted naphthalene, perylene, benzo(g,h,i)perylene, phenanthrene, C1 substituted phenanthrene/anthracene, C2 substituted phenanthrene/anthracene, C3 substituted phenanthrene/anthracene, C4 substituted phenanthrene/anthracene, pyrene, C1 substituted fluoranthene/pyrene, C2 substituted fluoranthene/pyrene, C3 substituted fluoranthene/pyrene, C4 substituted fluoranthene/pyrene, indeno(1,2,3-cd)pyrene, benzo(a)pyrene, benzo(e)pyrene, retene
Polycyclic Aromatic Nitrogen Heterocycles (PANHs)[c]	Acridine and quinoline
Sediment Samples	
Particle Size	Particle size (sand, silt, clay), moisture content
Carbon Content	Total organic carbon (TOC), total inorganic carbon and total carbon
Toxicity[d]	Survival and growth of *Chironomus dilutus* and *Hyalella azteca*
Organics	Total volatile, extractable and petroleum hydrocarbons[e]
Metals (Total)	Aluminum, antimony, arsenic, barium, beryllium, boron, calcium, cadmium, chromium, cobalt, copper, iron, lead, mercury, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, thallium, titanium, uranium, vanadium and zinc
Target Polycyclic Aromatic Hydrocarbons (PAHs) and Alkylated PAHs	Acenaphthene, C1 substituted acenaphthene, acenaphthylene, anthracene, dibenz(a,h)anthracene, benzo(a)anthracene, benzo(c)phenanthrene, C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene, C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene, biphenyl, C1 substituted biphenyl, C2 substituted biphenyl, chrysene, C1 substituted benzo(a)anthracene/chrysene, C2 substituted benzo(a)anthracene/chrysene, C3 substituted benzo(a)anthracene/chrysene, C4 substituted benzo(a)anthracene/chrysene, dibenzothiophene, C1 substituted dibenzothiophene, C2 substituted dibenzothiophene, C3 substituted dibenzothiophene, C4 substituted dibenzothiophene, fluoranthene, benzo(b&j)fluoranthene, benzo(k)fluoranthene, fluorene, C1 substituted fluorene, C2 substituted fluorene, C3 substituted fluorene, naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, C1 substituted naphthalene, C2 substituted naphthalene, C3 substituted naphthalene, C4 substituted naphthalene, perylene, benzo(g,h,i)perylene, phenanthrene, C1 substituted phenanthrene/anthracene, C2 substituted phenanthrene/anthracene, C3 substituted phenanthrene/anthracene, C4 substituted phenanthrene/anthracene, pyrene, C1 substituted fluoranthene/pyrene, C2 substituted fluoranthene/pyrene, C3 substituted fluoranthene/pyrene, C4 substituted fluoranthene/pyrene, indeno(1,2,3-cd)pyrene, benzo(a)pyrene, benzo(e)pyrene, retene
Polycyclic Aromatic Nitrogen Heterocycles (PANHs)	Acridine and quinoline

[a] The same list of parameters was analyzed in the 2017 water and sediment samples for which data are summarized in this report.

[b] Only total methyl mercury was analyzed.

[c] Target polycyclic aromatic hydrocarbons (PAHs), alkylated PAHs, and polycyclic aromatic nitrogen heterocycles (PANHs) were only analyzed in the sample collected at Station NNL-1 in Muskeg Lake.

[d] Sediment toxicity samples were only collected at Station WAC-1 and Station AB07DA0440 during the fall.

[e] F1/BTEX (a fraction of extractable hydrocarbons) was collected twice per station using two different sampling methods (i.e., sample collected in methanol vials and sample collected in soil jars) for watercourse stations and analyzed twice by the laboratory.

4.2.2 Quality Assurance and Quality Control

Water and sediment quality duplicate and split samples, and water quality field blanks were collected for quality control (QC) purposes as part of the 2018 monitoring program (Appendix III, Tables III-1 to III-3). Results for QC samples were used to evaluate potential contamination of samples during sampling and laboratory analysis, and to assess within-station variability, precision of field sampling methods, and analytical precision of laboratory analysis, as described below.

In the field blank, detected concentrations were considered notable if they were greater than five times the corresponding detection limit (DL).

In split and duplicate water samples, differences between concentrations of a parameter were considered notable if:

- they were greater than 30% for Polycyclic Aromatic Hydrocarbons (PAHs) and Polycyclic Aromatic Nitrogen Heterocycles (PANHs);
- they were greater than 20% for all other parameters; and
- concentrations were greater than five times the reported DLs in both samples.

In split and duplicate sediment samples, differences between concentrations of a parameter were considered notable if:

- they were greater than 50% for PAHs and PANHs;
- they were greater than 35% for all other parameters; and
- concentrations were greater than five times the reported DLs in both samples.

Within-station variability and field sampling precision in duplicate water and sediment samples were rated as:

- low and high, respectively, if less than 10% of the parameters included in the duplicate sample analysis were notably different from one another;
- moderate if 10 to 30% of the parameters included in the duplicate sample analysis were notably different from one another; or
- high and low, respectively, if more than 30% of the parameters included in the duplicate sample analysis were notably different from one another.

Analytical precision in split water and sediment samples was rated as:

- high if less than 10% of the parameters included in the split sample analysis were notably different from one another;
- moderate if 10 to 30% of the parameters included in the split sample analysis were notably different from one another; or
- low if more than 30% of the parameters included in the split sample analysis were notably different from one another.

4.3 Methods for Five-Year Water/Sediment Monitoring Data Summary

To provide the current five-year summary of Kearl monitoring data and integration with regional monitoring data, water quality and sediment quality data that have been collected for Kearl from 2006 to 2018 were combined with historical data from the following sources:

- RAMP database (RAMP 2018);
- AEP Water Data System (WDS; AEP 2018); and
- baseline data for the Project as presented in the previous five-year Kearl monitoring summary in the 2013 Annual Monitoring Report (Golder 2013a).

Methods describing the analysis of historical water quality and sediment data are provided below.

4.3.1 Watercourses and Kearl Lake

4.3.1.1 Water Quality

Qualitative comparisons were used to evaluate water quality in the Firebag River, Muskeg River, Wapasu Creek, Muskeg Creek, Iyinimin Creek and Kearl Lake before and after project operations began.

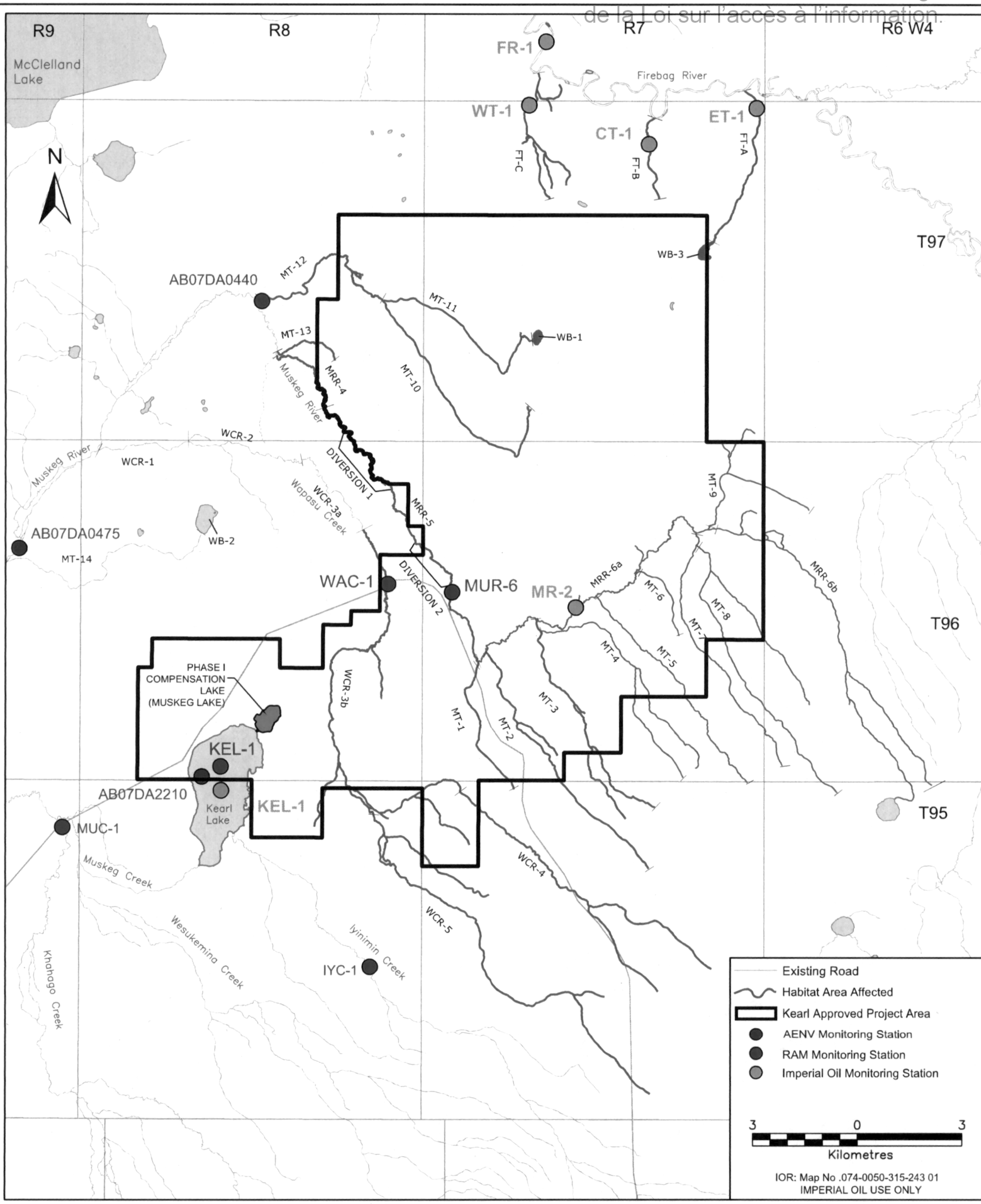
Compiled water quality data collected from all monitoring stations sampled from 2006 to 2018 (Figure 4-1) were split into four watersheds: the Firebag River and its tributaries (ET-1, CT-1, WT-1, and FR-1), Muskeg River (MR-2, MUR-6, AB07DA0440, and AB07DA0475), Muskeg Creek (IYC-1, KEL-1, and MUC-1), and Wapasu Creek (WAC-1) (Appendix IV, Tables IV-1 to IV-4).

Data from each watershed were summarized by season for the baseline phase (2006 to 2010) and the Kearl operational phase (2011 to 2018) (Appendix V, Tables V-1 to V-8). For each watershed, seasonal summary statistics were calculated for each of the two phases (i.e., minimum, maximum, mean, median, 95th percentile, count, and count of non-detectable values). In cases where more than 25% of results were less than the (DL, the mean and standard deviation were not calculated.

Seasons were defined as:

- Winter: November through March
- Spring: April and May
- Summer: June through August
- Fall: September and October

Seasonal data for each watershed were compared to the acute and chronic surface water guidelines for the protection of freshwater aquatic life (WQGs) published by the Government of Alberta (GOA 2018) (Appendix V). Water quality data were also evaluated against the Canadian Drinking Water Quality Guidelines published by Health Canada (HC 2017). Data were compared to the drinking water maximum acceptable concentrations (MACs) and aesthetic objectives (AOs). Drinking water AOs do not necessarily indicate a risk to human health (HC 2017); the drinking water AOs are intended to indicate the suitability of water for industrial or domestic uses (e.g., laundry), rather than to identify health concerns. Comparison to the drinking water MACs and AOs (HC 2017) were completed in Appendix V but exceedances of drinking water AOs were not discussed as part of the results in Section 4.7.1. Surface water quality data were also evaluated against GOA (2018) livestock and wildlife drinking water guidelines (wildlife guidelines) as an indicator of risk to wildlife health.



Version: 3

NOTES:

Imperial

IMPERIAL OIL RESOURCES

KEARL - MINING
WATER QUALITY MONITORING STATIONS BY OPERATOR
AQUATICS SITE LOCATIONS MAP

PROJECTION	DATUM	CONTRACTOR NAME	CONTRACTOR DRAWING NUMBER
UTM 12N	NAD83	GOLDER ASSOCIATES LTD.	FIGURE 4-1

DRAWN	CHECK	DESIGN	APPR.	DATE	SCALE	MAP NUMBER	REV
RFM	CB			19 03 25	1:150,000	074-0050-315-243 01	A

A-PSTD

Filename: L:\IMPERIAL_OIL\KEARLMINING\18110265\02_PRODUCTION\100\DWG\18110265_100-HS-0003.DWG User ID: BMCDONALD Plot date/time: March 25, 2019 - 9:18am

Temporal trends of water quality parameter concentrations were evaluated qualitatively using time series scatter plots. Parameters that demonstrated trends over time are presented and discussed in detail in Section 4.7.2. If a trend occurred in both the total and dissolved concentrations of a metal parameter, only the scatter plot of the total concentration was presented.

4.3.1.2 Sediment Quality

Sediment quality data were compiled for stations in the Firebag River (Station FR-1), Muskeg River (Stations MUR-D2, MUR-D3, and AB07DA0440), Wapasu Creek (Station WAC-1), and Kearl Lake (Station KEL-1) for the baseline phase (2006 to 2010) and the Kearl operational phase (2011 to 2018) (Appendix VI). Sediment quality data for each station were compared to the CCME interim sediment quality guidelines (ISQG) and probable effects level (PEL) guidelines (CCME 1998) for both the baseline and operational phases (Appendix VI).

4.3.2 Muskeg Lake

4.3.2.1 Water Quality

Water quality samples were collected in Muskeg Lake (Station NNL-1) from the lake filling phase to the present (i.e., from 2012 to 2018), typically in three seasons each year. Additionally, sediment quality samples were collected from Muskeg Lake once a year in either late summer or fall from 2013 to 2018. Composite water samples were collected from up to five locations across the lake for analysis of the full water quality parameter list including PAHs and PANHs. For some programs, less than five samples were collected due to timing restrictions or weather. Water quality data were compared to chronic and acute WQGs (GOA 2018), wildlife guidelines (GOA 2018) and the drinking water MACs and AOs (HC 2017). Comparison to the drinking water AOs (HC 2017) were presented in Section 4.8.1 for reference, but exceedances were not discussed.

Temporal trends of water quality parameter concentrations were evaluated qualitatively; time series scatter plots are presented in Appendix VII. Parameters that demonstrated trends over time are presented and discussed in Section 4.8.2. If a trend occurred in both the total and dissolved concentrations of a metal parameter, only the scatter plot of the total concentration was presented.

4.3.2.2 Sediment Quality

Sediment quality data collected from 2013 to 2018 at Muskeg Lake were compared to the interim sediment quality guidelines (ISQG) and probable effects level (PEL) guidelines (CCME 1998).

4.4 Methods for Comparison of Muskeg Lake Data to Predicted Conditions

Muskeg Lake was constructed to provide productive aquatic habitats to compensate for Kearl effects on fish productivity in affected natural habitats, as described in the Kearl NNLP (Imperial Oil 2007). Muskeg lake represents Phase I of compensation habitat development, with two additional lake phases to be constructed as Kearl development continues. As part of the NNLP, model predictions were generated to estimate the general suitability of Muskeg Lake as productive aquatic habitat, and to provide specific inputs for fish Habitat Suitability Index (HSI) modelling (see Section 5.6.8). Phase I (2007 to 2024) water quality predictions were made regarding Muskeg Lake trophic status, total dissolved solids concentrations, and temperature and dissolved oxygen characteristics. Water from Kearl Lake was used to fill Muskeg Lake, so conditions in Muskeg Lake were generally predicted to be similar to or to approach Kearl Lake over time. Specific predictions were as follows.

- Trophic status: Historical data suggest Kearl Lake is mesotrophic (moderately productive) to meso-eutrophic (moderately to highly productive); therefore, Muskeg Lake was predicted to eventually be mesotrophic to meso-eutrophic. However, during the beginning of Phase I, Muskeg Lake nutrient concentrations are predicted to be less than those in Kearl Lake but approaching Kearl Lake values over time.
- Temperature: Muskeg Lake was predicted to be vertically isothermal throughout the year (i.e., not thermally stratified). A typical seasonal pattern observed in a year would include temperatures ranging between 0°C and 3°C from October to May, increasing until summer with an average range of 15°C to 24°C in July and August, before declining through fall back to 0°C to 3°C.
- Dissolved oxygen: Dissolved oxygen concentrations in Muskeg Lake were predicted to be highest in fall and lowest in winter. Dissolved oxygen concentrations during the open water period were predicted to typically be above 7 mg/L, with negligible stratification. Dissolved oxygen concentrations during ice cover were predicted to continuously decrease until reaching lowest levels in late winter. In late winter, dissolved oxygen concentrations were predicted to be 0 mg/L within 1 m of the sediment (lake bed) and greater than 5.0 mg/L for the portion of the water column more than 1 m above the sediment. Excluding the bottom 1 m of water, mean water column dissolved oxygen concentrations in the Phase I lake were predicted to be on average about 7.5 mg/L.
- Total dissolved solids: TDS concentrations for the Phase I lake were predicted to be generally similar to Kearl Lake and to range from approximately 230 mg/L to 245 mg/L. In the long term (over approximately 200 years), TDS concentrations were predicted to increase slightly (about 30 mg/L). Concentrations of TDS were predicted to follow a seasonal pattern; higher in the winter due to salt exclusion from ice, and lower in the spring due to dilution. Adequate circulation was predicted to occur in Muskeg Lake, and there should not be a build up of salts that may impact the suitability of the habitat for fish.

To address the predictions outlined in the NNLP (Imperial Oil 2007), the following steps were taken.

- Trophic Status: Nutrient concentrations from all available samples collected at Stations NNL-1 and KEL-1 from start of Muskeg Lake monitoring (i.e., from 2012 to 2018) were compiled and used to determine trophic status in both lakes for each year based on criteria in Vollenweider and Kerekes (1980). Open water data from late summer were used to evaluate the most productive season in the lakes (with the exception of one May 2012 sample, which was included because only spring data were available that year). Trophic status was compared between lakes to evaluate if Muskeg Lake meets the NNLP prediction and has a similar trophic level as Kearl Lake.

- Temperature: Temperature profiles collected at Stations NNL-1 and KEL-1 during 2018 were plotted to determine if the lakes were isothermal. Seasonal patterns were determined qualitatively and compared between lakes and to NNLP predictions.
- Dissolved oxygen: Dissolved oxygen profiles collected at Stations NNL-1 and KEL-1 during 2018 were plotted to determine if the lakes were stratified with respect to dissolved oxygen concentration. Seasonal patterns were determined qualitatively and compared between lakes and to NNLP predictions.
- Total dissolved solids: Patterns in TDS concentrations in Muskeg Lake from 2012 to 2018 were determined qualitatively based on the time series plot and then compared to NNLP predictions.

4.5 2017 Water and Sediment Quality Results

Results for water quality, sediment quality/toxicity, and QC samples collected in fall 2017 that were not available at the time of preparation of the 2017 Annual Monitoring Report are presented here.

4.5.1 Water Quality

Field and analytical water quality data for samples collected at Stations AB07DA0440, FR-1, and MR-2 in late October 2017 are summarized in Table 4-4. Concentrations of water quality parameters were within typical ranges observed in the oil sands Region, as reported by RAM (JOSMP 2016), with the exception of field pH at Stations AB07DA0440 and MR-2, which were lower than the pH recorded in the region (Table 4-4; JOSMP 2016). The concentrations of all water quality parameters (including field pH) were consistent with the data collected in previous monitoring years (Golder 2013a, 2014, 2015, 2017a, 2017b). Key observations from the data are described below.

Parameters measured in fall 2017 were within typical ranges observed in previous years at Stations AB07DA0440, FR-1, and MR-2. Concentrations of carbonate, sulphate, nitrate, nitrite, nitrate + nitrite, naphthenic acids, phenol, total recoverable hydrocarbons, total and dissolved beryllium, selenium, and silver, and dissolved cadmium, copper, lead, thallium, titanium, and vanadium were below the DL at all stations.

Because of logistical constraints, dissolved mercury samples at Stations AB07DA0440, FR-1, and MR-2 were filtered and preserved by InnoTech past the recommended 48-hour hold time. However, all dissolved mercury concentrations were less than the corresponding total concentrations, and therefore filtering and preserving after the recommend hold time does not appear to have affected the data.

Table 4-4: Water Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit	AB07DA0440	FR-1	MR-2
		24-Oct-17	26-Oct-17	24-Oct-17
Field Measured				
pH	-	7.0	7.9	7.1
Specific conductivity	µS/cm	446	153	291
Temperature	°C	4.2	0.7	3.5
Dissolved oxygen	mg/L	3.0	12.7	4.5
Conventional Parameters				
pH[(a)]	-	8.1	8.1	8.1
Specific conductivity	µS/cm	520	170	340
Hardness, as $CaCO_3$	mg/L	280	82	190
Total alkalinity, as $CaCO_3$	mg/L	270	84	180
Total dissolved solids	mg/L	310	110	220
Total suspended solids	mg/L	10[(a)]	6	12

Table 4-4: Water Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit	AB07DA0440	FR-1	MR-2
		24-Oct-17	26-Oct-17	24-Oct-17
Total organic carbon	mg/L	21	11	20
Dissolved organic carbon	mg/L	20	12	20
Colour	TCU	99	48	52
Major Ions				
Bicarbonate, as $CaCO_3$	mg/L	330	100	220
Calcium	mg/L	76	22	47
Carbonate, as $CaCO_3$	mg/L	<1	<1	<1
Chloride	mg/L	5	1	2
Magnesium	mg/L	22	6.8	19
Potassium	mg/L	1.3	0.68	2.1
Sodium	mg/L	7.8	3.3	4.4
Sulphate	mg/L	<1	<1	<1
Sulphide	mg/L	0.0110	<0.0019	0.0089
Nutrients and Biological Indicators				
Nitrate	mg-N/L	<0.01	<0.01	<0.01
Nitrate + nitrite	mg-N/L	<0.014	<0.014	<0.014
Nitrite	mg-N/L	<0.01	<0.01	<0.01
Nitrogen - ammonia	mg-N/L	0.450	<0.015	0.053
Nitrogen - Kjeldahl	mg-N/L	1.3	0.43	1.0
Phosphorus, total	mg-P/L	0.083	0.050	0.110
Phosphorus, dissolved	mg-P/L	0.018	0.018	0.022
Biochemical oxygen demand	mg/L	6	3	< 2
General Organics				
Naphthenic acids	mg/L	<1	<1	<1
Phenol	mg/L	<0.002	<0.002	<0.002
Total recoverable hydrocarbons	mg/L	<2	<2	<2
Metals (Total)				
Aluminum	µg/L	16	18	100
Antimony	µg/L	<0.02	<0.02	0.05
Arsenic	µg/L	0.32	0.29	0.34
Barium	µg/L	50	22	30
Beryllium	µg/L	<0.01	<0.01	<0.01
Boron	µg/L	23	11	<10
Cadmium	µg/L	<0.005	<0.005	0.008
Chromium	µg/L	0.2	<0.1	0.2
Cobalt	µg/L	0.230	0.059	0.210
Copper	µg/L	0.2	0.3	0.3
Iron	µg/L	4,900	630	1,400
Lead	µg/L	0.03	<0.02	0.10
Lithium	µg/L	8.9	3.8	4.9
Manganese	µg/L	420	51	140
Mercury	µg/L	0.00065	0.00071	0.00075
Methyl Mercury	µg/L	0.00022	<0.00008	0.00013
Molybdenum	µg/L	<0.05	0.14	0.10
Nickel	µg/L	0.25	0.21	0.62
Selenium	µg/L	<0.04	<0.04	<0.04

Table 4-4: Water Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit	AB07DA0440	FR-1	MR-2
		24-Oct-17	26-Oct-17	24-Oct-17
Silver	µg/L	<0.01	<0.01	<0.01
Strontium	µg/L	150	43	86
Thallium	µg/L	<0.002	<0.002	<0.002
Titanium	µg/L	<2	<2	2
Uranium	µg/L	0.028	0.025	0.087
Vanadium	µg/L	0.3	0.2	0.3
Zinc	µg/L	1	<1	3
Metals (Dissolved)				
Aluminum	µg/L	3.0	3.1	4.1
Antimony	µg/L	0.02	<0.02	0.04
Arsenic	µg/L	0.24	0.23	0.27
Barium	µg/L	49	19	29
Beryllium	µg/L	<0.01	<0.01	<0.01
Boron	µg/L	24	11	< 10
Cadmium	µg/L	<0.005	<0.005	<0.005
Chromium	µg/L	0.2	<0.1	<0.1
Cobalt	µg/L	0.210	0.032	0.130
Copper	µg/L	<0.05	<0.05	<0.05
Iron	µg/L	780	260	400
Lead	µg/L	<0.005	<0.005	<0.005
Lithium	µg/L	9.6	3.6	5.3
Manganese	µg/L	440	4.8	120
Mercury[a]	µg/L	0.00031	0.00037	0.00027
Molybdenum	µg/L	<0.05	0.15	0.09
Nickel	µg/L	0.22	0.15	0.48
Selenium	µg/L	<0.04	<0.04	<0.04
Silver	µg/L	<0.005	<0.005	<0.005
Strontium	µg/L	170	44	91
Thallium	µg/L	<0.002	<0.002	<0.002
Titanium	µg/L	<0.5	<0.5	<0.5
Uranium	µg/L	0.030	0.028	0.083
Vanadium	µg/L	<0.2	<0.2	<0.2
Zinc	µg/L	0.7	0.1	0.5

[a] Parameter was analysed past the recommended hold time.

Note: - = not applicable; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre.

4.5.2 Sediment Quality

Analytical results for sediment quality samples collected at Stations AB07DA0440, FR-1, and WAC-1 in fall 2017 are summarized in Table 4-5. Concentrations of sediment quality parameters were generally within typical ranges observed in previous years (Golder 2013a, 2014, 2015, 2017a, 2017b). Sand was the dominant fraction of inorganic bottom sediments and TOC content was low at all stations. At Station FR-1, moisture content was below the typical range observed in previous years (Table 4-5; Golder 2013a, 2014, 2015, 2017a, 2017b).

Hydrocarbon and PAH/PANH concentrations were generally below the DLs at all stations. Detectable concentrations of acenaphthylene, benzo(a)anthracene, benzo(k)fluoranthene, and benzo(e)pyrene at Station FR-1 were above the range of historical data from previous monitoring programs and likely due to eroded oil sands (Table 4-5; Golder 2013a, 2014, 2015, 2017a, 2017b). Detectable concentrations of anthracene at Station WAC-1 were also above the range of historical data from previous monitoring programs. All other detectable concentrations of PAH/PANHs were within the range of historical data.

Table 4-5: Sediment Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit [dry wt.]	AB07DA0440 24-Oct-17	FR-1 26-Oct-17	WAC-1 25-Oct-17
Particle Size				
Sand content	%	95	96	94
Silt content	%	3	2	4
Clay content	%	<2	2	2
Moisture content	%	31	12	32
Carbon Content				
Total inorganic carbon	%	0.29	<0.05	0.19
Total organic carbon	%	1.1	1.2	1.2
Total carbon	%	1.4	1.1	1.4
Organics				
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	<10	<10	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	<10	230	13
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	120	2,300	140
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	<50	1,400	<50
Total petroleum hydrocarbons	mg/kg	59	5,700	<50
Metals (Total)				
Aluminum	mg/kg	650	640	730
Antimony	mg/kg	<0.5	<0.5	<0.5
Arsenic	mg/kg	<1	2	<1
Barium	mg/kg	13	8	19
Beryllium	mg/kg	<0.4	<0.4	<0.4
Boron	mg/kg	<2	<2	<2
Cadmium	mg/kg	<0.05	<0.05	<0.05
Calcium	mg/kg	1,900	5,100	1,600
Chromium	mg/kg	2	2	1
Cobalt	mg/kg	0.8	1.1	0.7
Copper	mg/kg	<1	2	<1
Iron	mg/kg	2,600	4,900	2,000
Lead	mg/kg	0.5	1.1	0.6
Lithium	mg/kg	<10	<10	<10
Magnesium	mg/kg	650	2,900	380
Manganese	mg/kg	33	30	150
Mercury	mg/kg	<0.05	<0.05	<0.05

Table 4-5: Sediment Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit [dry wt.]	AB07DA0440	FR-1	WAC-1
		24-Oct-17	26-Oct-17	25-Oct-17
Molybdenum	mg/kg	<0.4	<0.4	<0.4
Nickel	mg/kg	2	3	<1
Potassium	mg/kg	<50	<50	<50
Selenium	mg/kg	<0.5	<0.5	<0.5
Silver	mg/kg	<0.2	<0.2	<0.2
Sodium	mg/kg	<50	<50	<50
Strontium	mg/kg	<10	<10	<10
Thallium	mg/kg	<0.1	<0.1	<0.1
Titanium	mg/kg	25	35	12
Uranium	mg/kg	<0.2	0.3	<0.2
Vanadium	mg/kg	2	5	2
Zinc	mg/kg	<10	<10	<10
Target PAHs and Alkylated PAHs				
Acenaphthene	mg/kg	<0.0005	<0.0005	<0.0005
C1 substituted acenaphthene	mg/kg	<0.005	<0.005	<0.005
Acenaphthylene	mg/kg	<0.0005	0.0081	<0.0005
Anthracene	mg/kg	<0.0005	<0.005	0.0007
Dibenzo(a,h)anthracene	mg/kg	<0.001	0.015	<0.001
Benzo(a)anthracene	mg/kg	<0.0005	0.0100	<0.0005
Benzo(c)phenanthrene	mg/kg	<0.005	<0.05	<0.005
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	<0.005	0.340	<0.005
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	<0.005	0.190	<0.005
Biphenyl	mg/kg	<0.005	<0.005	<0.005
C1 substituted biphenyl	mg/kg	<0.005	<0.005	<0.005
C2 substituted biphenyl	mg/kg	<0.005	0.009	<0.005
Chrysene	mg/kg	<0.0005	<0.005	<0.0005
C1 substituted benzo(a)anthracene/chrysene	mg/kg	<0.005	0.330	<0.005
C2 substituted benzo(a)anthracene/chrysene	mg/kg	<0.005	1.8	0.008
C3 substituted benzo(a)anthracene/chrysene	mg/kg	<0.005	0.880	<0.005
C4 substituted benzo(a)anthracene/chrysene	mg/kg	<0.005	0.200	<0.005
Dibenzothiophene	mg/kg	<0.005	<0.005	<0.005
C1 substituted dibenzothiophene	mg/kg	<0.005	<0.005	<0.005
C2 substituted dibenzothiophene	mg/kg	<0.005	0.240	0.011
C3 substituted dibenzothiophene	mg/kg	<0.005	0.340	<0.005
C4 substituted dibenzothiophene	mg/kg	<0.005	1.1	0.015
Fluoranthene	mg/kg	<0.0005	<0.005	<0.0005
Benzo(b&j)fluoranthene	mg/kg	0.0007	0.0530	0.0007
Benzo(k)fluoranthene	mg/kg	<0.0005	0.0064	<0.0005
Fluorene	mg/kg	0.003	<0.005	0.003
C1 substituted fluorene	mg/kg	<0.005	0.009	<0.005
C2 substituted fluorene	mg/kg	<0.005	0.046	<0.005
C3 substituted fluorene	mg/kg	0.008	<0.005	<0.005
Naphthalene	mg/kg	<0.0005	<0.005	0.001
1-Methylnaphthalene	mg/kg	<0.005	<0.005	<0.005
2-Methylnaphthalene	mg/kg	<0.005	<0.05	<0.005
C1 substituted naphthalene	mg/kg	<0.005	<0.005	<0.005

Table 4-5: Sediment Quality Data for Watercourse Monitoring Stations, Fall 2017

Parameter	Unit [dry wt.]	AB07DA0440	FR-1	WAC-1
		24-Oct-17	26-Oct-17	25-Oct-17
C2 substituted naphthalene	mg/kg	0.017	0.030	0.023
C3 substituted naphthalene	mg/kg	<0.005	0.016	<0.005
C4 substituted naphthalene	mg/kg	<0.005	0.037	<0.005
Perylene	mg/kg	0.022	0.067	<0.005
Benzo(g,h,i)perylene	mg/kg	<0.001	0.032	<0.001
Phenanthrene	mg/kg	0.001	<0.005	0.001
C1 substituted phenanthrene/anthracene	mg/kg	<0.005	0.030	<0.005
C2 substituted phenanthrene/anthracene	mg/kg	<0.005	0.120	<0.005
C3 substituted phenanthrene/anthracene	mg/kg	0.013	0.420	0.019
C4 substituted phenanthrene/anthracene	mg/kg	0.038	1.2	0.052
Pyrene	mg/kg	0.0016	0.0820	<0.0005
C1 substituted fluoranthene/pyrene	mg/kg	<0.005	0.380	<0.005
C2 substituted fluoranthene/pyrene	mg/kg	0.170	1.3	0.011
C3 substituted fluoranthene/pyrene	mg/kg	0.020	3.2	0.011
C4 substituted fluoranthene/pyrene	mg/kg	<0.005	1.9	0.010
Indeno(1,2,3-cd)pyrene	mg/kg	<0.001	0.016	<0.001
Benzo(a)pyrene	mg/kg	<0.0005	0.031	<0.0005
Benzo(e)pyrene	mg/kg	<0.005	0.073	<0.005
Retene	mg/kg	0.048	<0.005	0.056
PANHs				
Acridine	mg/kg	<0.01	<0.01	<0.01
Quinoline	mg/kg	<0.01	-[a]	<0.01

[a] Quinoline recovery not calculated due to required dilution caused by sample matrix.

Note: dry wt. = dry weight; < = less than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

4.5.2.1 Sediment Toxicity

Sediment toxicity test samples were collected in fall 2017 at two watercourse monitoring stations located downstream of the Kearl area; Station AB07DA0440 (Muskeg River) and Station WAC-1 (Wapasu Creek). Five replicate sediment sub-samples were collected for analysis for both stations.

The 2017 sediment toxicity test results show that survival of *Chironomus dilutus* at Station AB07DA00440 and *Hyalella azteca* at both stations was approximately equal to that of the laboratory control, indicating no adverse effect on survival of test organisms (Table 4-6). *Chironomus dilutus* survival at Station WAC-1 was significantly lower than the control. Growth of *Chironomus dilutus* and *Hyalella azteca* was higher relative to the control at both stations, with the exception of growth of *Chironomus dilutus* at Station AB07DA0440, which was significantly reduced relative to the control.

Table 4-6: Sediment Toxicity Results for Watercourse Monitoring Stations, Fall 2017

Location	Test and Indicator	Mean Survival ± SD (% of control)	Mean Growth ± SD (% of control)
Muskeg River – Station AB07DA0440	*Chironomus dilutus*: 10-d Growth and Survival Test	100 ± 5	78 ± 8[a]
	Hyalella azteca: 14-d Growth and Survival Test	100 ± 0	153 ± 33
Wapasu Creek – Station WAC-1	*Chironomus dilutus*: 10-d Growth and Survival Test	69 ± 44[a]	124 ± 26
	Hyalella azteca: 14-d Growth and Survival Test	100 ± 0	133 ± 13

Note: SD = standard deviation; d = day.

[a] Statistically significant decrease relative to the control.

4.5.3 Quality Control

4.5.3.1 Water Quality

Concentrations of water quality parameters in the field blank collected during the fall 2017 monitoring program were generally not notable (i.e., were below five times the DL), with the exception of dissolved phosphorus (0.008 mg-P/L; Appendix III, Table III-1). Although the concentration of total phosphorus was greater than five times the DL, it was still below the concentration of the corresponding fall 2017 water quality field samples. The difference between total phosphorus measured in the field samples and the field blank was greater than five times the DL; therefore, field sample contamination was not suspected. Overall, the results indicate that field samples collected during 2017 sampling programs were free of contamination.

Results for four of the 79 parameters analyzed (excluding pH) were above the duplicate sample QC criterion in water samples collected in fall 2017, which represents 5% of the total analyzed parameters (Appendix III, Table III-3). Therefore, within-station variability and field sampling precision were rated as low and high, respectively, for fall 2017.

4.5.3.2 Sediment Quality

Three of the 95 parameters analyzed were above the split sample QC criterion in sediment samples collected in fall 2017, which represents 3% of the total analyzed parameters (Appendix III, Table III-2). No notable differences were detected between split sample concentrations in the PAH/PANH data. Therefore, analytical precision was rated as high for fall 2017.

4.6 2018 Water and Sediment Quality Results

4.6.1 Watercourse Monitoring Stations

4.6.1.1 Water Quality

Field and analytical water quality data from the 2018 monitoring program for watercourse monitoring stations are summarized in Table 4-7. Concentrations of water quality parameters from the 2018 monitoring program were generally within typical ranges observed in the oil sands Region, as reported by RAM (JOSMP 2016), with the exception of some pH, major ions, total alkalinity, and total aluminum values. Concentrations of water quality parameters from the 2018 monitoring program were generally consistent with the data collected in previous monitoring years with the exception of some dissolved oxygen, dissolved calcium, magnesium and manganese values (Golder 2013a, 2014, 2015, 2017a, 2017b). Key observations from the data are described below.

Field measurements were within typical ranges observed in previous years. In-situ pH values measured at Stations AB07DA0440, WAC-1, FR-1, MUR-6, and MR-2 in March, August and/or October were lower than those typically observed in the oil sands Region but were consistent with historical data for these sites.

Conventional parameters and nutrients were within the historical ranges and generally similar to concentrations observed in the oil sands Region, with the exception of total alkalinity at Station IYC-1 in March, which was higher than the range observed in the oil sands Region. Most major ions were within the historical ranges, except for calcium at Station AB07DA0440 and magnesium at Station MUR-6 in March. When compared to the typical values observed in the oil sands Region, major ions were measured at similar concentrations, except for calcium at Station AB07DA0440, sodium at Station IYC-1 and magnesium at Stations MR-2, MUR-6 and WAC-1 in March, which were higher than typical regional values.

Total and dissolved metal concentrations were within the historical ranges with the exception of dissolved manganese measured at Station MUR-6 in March, which was higher than the historical ranges (Golder 2013a, 2014, 2015, 2017a, 2017b). Concentration of dissolved manganese at Station MUR-6 were variable in 2018 and ranged from 8.3 μg/L in May to 1,600 μg/L in March. The historical range for data collected from 2007 to 2014 is 0.2 μg/L to 1,520 μg/L, indicating variability is typical for manganese concentrations at the monitoring stations. Total aluminum concentrations were within the typical range measured in previous programs but were lower than concentrations measured in the oil sands Region for three Station AB07DA0440 samples (May, August, and October), two Station MUR-6 samples (May and October), one Station WAC-1 sample (March) and one Station MR-2 sample (October). Due to field logistical constraints, all dissolved mercury samples were filtered and preserved by InnoTech past the recommended 48-hour hold time, but all dissolved mercury concentrations were lower than the corresponding total concentrations. Therefore, filtering and preserving after the recommended hold time did not appear to have affected the data.

Concentrations of carbonate, nitrite, total and dissolved silver, dissolved beryllium and cadmium, naphthenic acids, total recoverable hydrocarbons were below the DL at all sampling stations in all seasons. Phenol was detected at Stations AB07DA0440, FR-1, IYC-1 and WAC-1 in May and August, Station MR-2 in August, and Station MUR-6 in March, May and August but was within the historical range as well as typical ranges observed in the oil sands Region.

Table 4-7: Water Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit	AB07DA0440				FR-1				IYC-1				MR-2				MUR-6				WAC-1			
		09-Mar-18	15-May-18	22-Aug-18	17-Oct-18	08-Mar-18	14-May-18	05-Sep-18	15-Oct-18	08-Mar-18	14-May-18	05-Sep-18	15-Oct-18	10-Mar-18	15-May-18	22-Aug-18	18-Oct-18	10-Mar-18	14-May-18	21-Aug-18	18-Oct-18	10-Mar-18	14-May-18	21-Aug-18	16-Oct-18
Field Measured																									
pH	-	6.7	7.3	6.7	6.8	6.6	7.6	8.1	7.0	7.4	7.5	7.9	7.0	7.0	7.2	6.5	6.6	7.0	7.2	7.3	6.9	7.0	7.2	7.0	7.0
Specific conductivity	µS/cm	566	230	486	419	229	111	198	210	743	122	250	231	461	202	477	348	505	207	391	356	468	209	364	271
Temperature	°C	0.0	11.8	15.6	1.2	0.0	10.3	6.5	0.3	0.0	6.5	4.3	0.0	0.0	12.5	14.6	1.0	0.1	11.1	14.0	1.6	0.1	11.1	15.8	1.0
Dissolved oxygen	mg/L	4.8	8.3	1.7	6.0	5.4	11.0	13.7	28.5[a]	9.1	12.0	14.0	32.1[a]	2.5	5.4	1.2	4.3	6.9	9.1	5.0	11.3	4.3	9.0	1.5	11.7
Conventional Parameters																									
pH[b]	-	7.8	7.9	7.9	7.9	7.8	8.0	8.2	8.2	8.3	7.9	8.1	8.2	7.8	7.9	7.6	7.5	7.9	7.9	8.0	7.7	8.0	7.9	8.1	7.8
Specific conductivity	µS/cm	620	250	490	400	230	120	210	200	750	130	260	210	560	220	430	330	620	220	460	340	570	230	500	310
Hardness, as $CaCO_3$	mg/L	330	130	290	210	120	65	110	96	220	66	120	95	300	110	250	180	320	120	280	180	300	110	280	150
Total alkalinity, as $CaCO_3$	mg/L	310	110	260	200	110	56	100	96	380	56	130	99	300	100	220	170	310	110	260	180	290	87	260	140
Total dissolved solids	mg/L	360	170	320	210	140	100	110	130	400	120	220	150	300	290	310	220	320	160	330	210	320	170	300	190
Total suspended solids	mg/L	27	<1	2	<1	<1	18	<1	6	<1	47	<1	<1	130	<1	4	<1	7	<1	<1	<1	2	<1	<1	<1
Total organic carbon	mg/L	20	20	24	17	6	15	9	7	19	23	25	20	15	19	25	19	18	21	27	18	11	20	18	18
Dissolved organic carbon	mg/L	19	20	22	18	6	15	9	10	19	21	24	21	12	19	24	19	17	19	31	20	9	19	17	21
Colour	TCU	48	72	34	46	38	92	52	37	66	100	100	79	23	65	28	38	30	75	40	45	21	79	17	46
Major Ions																									
Bicarbonate	mg/L	380	140	320	250	140	69	130	120	460	68	150	120	370	130	270	210	380	130	320	220	350	110	320	170
Calcium	mg/L	100	33	77	54	29	18	28	25	59	17	31	25	74	29	64	42	81	32	65	44	84	27	68	35
Carbonate	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloride	mg/L	5	4	3	4	4	< 1	< 1	< 1	4	3	4	5	1	2	2	3	2	1	2	3	3	8	5	10
Magnesium	mg/L	27	11	24	17	9.8	5.2	8.1	7.9	23	5.5	10	8.2	30	10	23	16	36	11	21	16	28	9.4	23	12
Potassium	mg/L	1.7	1.6	0.97	1.1	0.99	0.59	0.60	0.54	2.3	0.82	0.62	0.36	1.4	1.3	0.77	1.0	2.0	1.3	0.77	0.75	1.5	2.1	1.3	1.0
Sodium	mg/L	7.7	4.8	7.0	6.1	3.9	2.7	3.2	3.4	100	5.2	13	10	3.5	3.1	5.1	4.1	5.1	3.4	4.3	4.2	8.7	7.9	8.2	8.9
Sulphate	mg/L	23	7	<1	7	2	<1	<1	<1	10	<1	<2	<1	<1	<1	<1	<1	<1	<1	<1	<1	4	17	<1	<1
Sulphide	mg/L	0.0130	<0.0019	0.0110	0.0076	<0.0019	<0.0019	0.0023	<0.0019	0.0027	0.0047	0.0045	0.0031	0.0140	<0.0019	0.0410	0.0062	0.0027	<0.0019	0.0110	0.0053	<0.0019	0.0043	0.0080	0.0100
Nutrients and Biological Indicators																									
Nitrate	mg-N/L	<0.01	<0.01	<0.01	0.01	0.31	<0.01	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate + nitrite	mg-N/L	<0.014	<0.014	<0.014	<0.014	0.310	<0.014	<0.014	<0.014	0.086	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	0.017	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014
Nitrite	mg-N/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen - ammonia	mg-N/L	0.750	0.018	0.150	0.047	0.052	<0.015	<0.015	<0.015	0.026	0.015	<0.015	<0.015	0.650	<0.015	0.097	0.031	0.700	0.018	0.029	0.022	0.360	0.020	0.023	<0.015
Nitrogen - Kjeldahl	mg-N/L	1.9	1.2	1.2	0.78	0.38	0.48	0.43	0.42	0.61	0.50	0.55	0.57	2.6	0.65	0.88	0.57	1.4	0.7	1.0	0.59	0.69	0.57	0.57	0.66
Phosphorus, total	mg-P/L	0.190	0.012	0.066	0.027	0.078	0.061	0.073	0.053	0.041	0.039	0.027	0.023	0.380	0.011	0.120	0.011	0.041	0.010	0.018	0.012	0.015	0.008	0.015	0.011
Phosphorus, dissolved	mg-P/L	<0.001	0.008	0.021	0.011	0.050	0.033	0.028	0.023	0.022	0.014	0.021	0.017	<0.001	0.007	0.071	0.006	<0.001	0.011	0.003	0.008	<0.001	0.007	0.010	0.004
Biochemical oxygen demand	mg/L	3[b]	<2[b]	2	<2	<2[b]	2	<2	<2	<2[b]	<2	<2	<2	4	<2	5	<2	2[b]	2	<2	<2	<2	<2	<2	<2
General Organics																									
Naphthenic acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Phenol	mg/L	<0.002	<0.002	0.008	<0.002	<0.002	0.005	0.005	<0.002	<0.002	0.005	0.007	<0.002	<0.002	<0.002	0.009	<0.002	0.005	0.004	0.010	<0.002	<0.002	0.005	0.005	<0.002
Total recoverable hydrocarbons	mg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Metals (Total)																									
Aluminum	µg/L	24	5.9	5.5	5.4	8.8	60	13	27	10	260	67	34	110	9.4	12	3.7	44	6.0	8.5	4.3	4.3	7.8	7.0	8.4
Antimony	µg/L	0.03	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.03	0.03	<0.02	0.08	0.03	0.02	0.03	0.03	0.03	0.02	0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	µg/L	0.33	0.26	0.60	0.24	0.29	0.37	0.35	0.29	0.58	0.57	0.70	0.49	0.42	0.29	1.1	0.28	0.43	0.30	0.81	0.28	0.13	0.24	0.26	0.23
Barium	µg/L	63	24	55	28	27	21	21	23	47	22	23	18	43	20	52	23	49	21	38	23	65	21	42	21
Beryllium	µg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 4-7: Water Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit	AB07DA0440				FR-1				IYC-1				MR-2				MUR-6				WAC-1			
		09-Mar-18	15-May-18	22-Aug-18	17-Oct-18	08-Mar-18	14-May-18	05-Sep-18	15-Oct-18	08-Mar-18	14-May-18	05-Sep-18	15-Oct-18	10-Mar-18	15-May-18	22-Aug-18	18-Oct-18	10-Mar-18	14-May-18	21-Aug-18	18-Oct-18	10-Mar-18	14-May-18	21-Aug-18	16-Oct-18
Boron	µg/L	29	21	21	14	14	18	14	12	410	29	56	42	<10	13	11	<10	<10	17	<10	<10	43	28	33	16
Cadmium	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	0.007	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	0.3	<0.1	0.1	0.1	<0.1	0.1	<0.1	0.1	<0.1	0.4	0.2	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
Cobalt	µg/L	0.270	0.068	0.340	0.091	0.041	0.100	0.047	0.058	0.250	0.300	0.190	0.120	0.690	0.057	0.600	0.099	1.00	0.078	0.520	0.100	0.380	0.070	0.170	0.082
Copper	µg/L	<0.1	<0.1	<0.1	<0.1	0.05	0.17	<0.1	<0.1	0.35	0.65	0.33	0.23	0.25	0.15	0.22	<0.1	0.11	0.11	<0.1	<0.1	0.10	<0.1	<0.1	<0.1
Iron	µg/L	5,300	260	3,100	720	760	710	470	660	1,000	730	860	620	3,300	150	3,600	260	2,300	240	860	350	1,300	170	350	320
Lead	µg/L	0.03	<0.02	<0.02	<0.02	0.01	0.06	<0.02	0.03	0.03	0.27	0.07	0.04	0.07	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	0.01	<0.02	<0.02	<0.02
Lithium	µg/L	9.8	5.4	7.8	6.8	4.0	2.9	3.8	4.0	24	4.2	6.9	6.1	5.3	3.7	5.4	4.1	5.7	3.8	5.9	4.4	8.9	7.0	8.9	8.3
Manganese	µg/L	520	17	850	100	35	60	19	47	49	28	25	25	910	14	860	84	1500	30	1200	100	690	15	200	63
Mercury	µg/L	0.00055[b]	0.00105	0.00096	0.00046	0.00047	0.00200	0.00075	0.00076	0.00187	0.00359	0.00158	0.00110	0.00076	0.00094	0.00140	0.00042	0.00082	0.00108	0.00120	0.00048	0.00034	0.00106	0.00068	0.00047
Methyl Mercury	µg/L	0.00014	0.00012	0.00026	0.00009	<0.00008	0.00012	0.00043	<0.00008	0.00009	0.00014	0.00015	0.00009	0.00015	0.00010	0.00055	0.00008	0.00026	0.00012	0.00017	<0.00008	0.00012	0.00013	0.00012	<0.00008
Molybdenum	µg/L	<0.05	0.13	<0.05	0.06	0.21	0.18	0.16	0.18	1.0	0.19	0.28	0.21	<0.05	0.18	0.10	0.11	<0.05	0.14	0.09	0.06	<0.05	0.08	<0.05	<0.05
Nickel	µg/L	0.37	0.42	0.43	0.35	0.10	0.35	0.16	0.20	0.98	1.0	1.0	0.62	0.51	0.55	0.75	0.47	0.48	0.47	0.71	0.37	0.23	0.35	0.34	0.27
Selenium	µg/L	<0.04	<0.04	0.05	<0.04	<0.04	<0.04	<0.04	<0.04	0.07	0.05	0.05	0.04	<0.04	<0.04	0.07	<0.04	0.04	<0.04	0.07	<0.04	<0.04	<0.04	<0.04	<0.04
Silver	µg/L	<0.01	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.01
Strontium	µg/L	220	73	170	110	59	38	56	50	190	49	84	64	110	60	130	86	140	62	140	78	130	74	130	81
Thallium	µg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.005	0.003	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	µg/L	<2	<2	<2	<2	<0.5	<2	<2	<2	1	10	3	<2	2	<2	<2	<2	<2	<2	<2	<2	<0.5	<2	<2	<2
Uranium	µg/L	0.120	0.024	0.026	0.039	0.039	0.034	0.037	0.038	0.610	0.057	0.100	0.053	0.062	0.033	0.014	0.048	0.030	0.017	0.030	0.030	0.150	0.010	0.130	0.019
Vanadium	µg/L	0.4	<0.2	<0.2	<0.2	<0.2	0.3	0.2	0.3	0.2	1.0	0.4	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	µg/L	3	1	3	<1	1	1	<1	<1	2	2	<1	<1	4	1	11	<1	2	<1	3	<1	2	<1	<1	<1
Metals (Dissolved)																									
Aluminum	µg/L	2.0	3.0	3.0	2.3	2.6	9.4	5.2	3.3	3.9	14	13	9.2	1.3	3.6	6.4	2.9	1.5	3.2	3.4	1.9	1.1	3.7	9.8	2.8
Antimony	µg/L	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	<0.02	0.03	0.05	0.02	<0.02	0.02	0.06	<0.02
Arsenic	µg/L	0.22	0.25	0.51	0.29	0.17	0.31	0.33	0.24	0.45	0.35	0.63	0.44	0.24	0.28	0.87	0.25	0.32	0.28	0.73	0.26	0.10	0.24	0.29	0.20
Barium	µg/L	48	22	44	25	27	15	20	20	44	16	23	17	34	20	45	23	44	19	35	23	62	18	46	22
Beryllium	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	25	21	18	11	13	15	13	12	370	26	57	42	<10	14	<10	<10	<10	15	12	<10	40	26	37	16
Cadmium	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt	µg/L	0.220	0.056	0.130	0.068	0.024	0.044	0.040	0.039	0.240	0.098	0.140	0.110	0.480	0.045	0.130	0.059	0.960	0.054	0.480	0.093	0.370	0.057	0.160	0.060
Copper	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	0.39	0.29	0.24	0.18	<0.05	0.13	<0.05	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	µg/L	210	160	790	420	360	290	290	270	280	150	600	470	60	83	1700	130	88	130	270	180	52	100	100	170
Lead	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	0.009	0.006	0.009	0.008	0.017	0.028	0.017	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	<0.005
Lithium	µg/L	8.8	5.0	7.6	6.6	4.3	2.8	4.1	3.8	24	3.8	7.4	5.7	4.7	3.5	5.4	4.4	5.7	3.9	5.3	4.8	9.2	6.8	9.3	8.1
Manganese	µg/L	490	8.2	83	69	16	4.2	6.2	11	47	7.0	18	18	830	5.3	68	33	1,600	8.3	960	86	720	5.6	88	31
Mercury	µg/L	0.00015[b]	0.00053	0.00070	0.00034	0.00020[b]	0.00118	0.00043	0.00045	0.0013[b]	0.00157	0.00111	0.00093	0.00024[b]	0.00052	0.00100	0.00036	0.00034[b]	0.00057[b]	0.00087[b]	0.00037	0.00014[b]	0.00052[b]	0.00034[b]	0.00039
Molybdenum	µg/L	<0.05	0.12	<0.05	0.06	0.19	0.16	0.16	0.16	0.98	0.17	0.26	0.19	<0.05	0.18	0.09	0.11	<0.05	0.12	0.09	0.08	<0.05	0.06	<0.05	0.06
Nickel	µg/L	0.28	0.37	0.41	0.29	0.09	0.25	0.15	0.13	1.0	0.61	0.81	0.56	0.36	0.51	0.74	0.43	0.46	0.41	0.68	0.38	0.20	0.29	0.32	0.28
Selenium	µg/L	<0.04	<0.04	0.06	<0.04	<0.04	<0.04	<0.04	<0.04	0.08	0.06	0.05	0.06	<0.04	0.04	0.09	<0.04	<0.04	0.04	0.06	<0.04	<0.04	<0.04	<0.04	0.04
Silver	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	µg/L	200	72	170	100	55	35	54	49	180	42	81	62	110	60	130	86	150	58	140	79	120	68	150	82
Thallium	µg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	0.7	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	µg/L	0.120	0.020	0.022	0.036	0.042	0.018	0.034	0.039	0.640	0.035	0.099	0.048	0.045	0.029	0.014	0.047	0.030	0.017	0.031	0.029	0.160	0.008	0.140	0.020
Vanadium	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	0.3	0.3	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	µg/L	1.5	0.8	1.1	0.2	0.4	0.3	0.4	0.1	1.1	0.3	0.3	0.2	1.1	1.0	5.1	0.3	1.1	0.2	1.5	0.3	0.9	0.3	0.2	0.6

(a) Dissolved oxygen result was invalidated due to suspected equipment malfunction.
(b) Parameter analyzed past the recommended hold time.
\- = not applicable or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre.

4.6.1.2 Sediment Quality

Analytical results for sediment quality samples collected at Stations AB07DA0440, FR-1, and WAC-1 in fall 2018 are summarized in Table 4-8. Concentrations of sediment quality parameters were generally within typical ranges observed in previous years (Golder 2013a, 2014, 2015, 2017a, 2017b). Sand was the dominant fraction of inorganic bottom sediments and TOC content was low at all stations. At Stations AB07DA0440 and WAC-1, anthracene was above the typical range observed in previous years (Golder 2013a, 2014, 2015, 2017a, 2017b). All other results were within the range of historical data.

Table 4-8: Sediment Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit [dry wt.]	AB07DA0440 17-Oct-18	AB07DA0440-A[a] 17-Oct-18	FR-1[b] 15-Oct-18	WAC-1 16-Oct-18	WAC-1-A[a] 16-Oct-18
Particle Size						
Sand content	%	96	-	96	95	-
Silt content	%	<2	-	<2	2	-
Clay content	%	3	-	2	3	-
Moisture content	%	37	55	19	31	33
Carbon Content						
Total inorganic carbon	%	<0.05	-	<0.05	<0.05	-
Total organic carbon	%	2.8	-	1.0	1.8	-
Total carbon	%	0.98	-	0.60	1.1	-
Organics						
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	<10	<20	<10	<10	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	<10	<22	180	<10	<10
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	380	240	1,600	100	140
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	55	<110	980	<50	70
Total petroleum hydrocarbons	mg/kg	98	-	4,400	130	-
Metals (Total)						
Aluminum	mg/kg	970	-	540	820	-
Antimony	mg/kg	<0.5	-	<0.5	<0.5	-
Arsenic	mg/kg	<1	-	<1	<1	-
Barium	mg/kg	18	-	11	19	-
Beryllium	mg/kg	<0.4	-	<0.4	<0.4	-
Boron	mg/kg	<2	-	<2	<2	-
Cadmium	mg/kg	<0.05	-	<0.05	<0.05	-
Calcium	mg/kg	2,000	-	1,800	1,900	-
Chromium	mg/kg	2	-	2	1	-
Cobalt	mg/kg	0.9	-	0.7	0.8	-
Copper	mg/kg	<1	-	<1	<1	-
Iron	mg/kg	4,000	-	2,500	2,600	-
Lead	mg/kg	0.8	-	1.0	0.6	-
Lithium	mg/kg	<10	-	<10	<10	-
Magnesium	mg/kg	700	-	1,100	370	-
Manganese	mg/kg	43	-	39	130	-
Mercury	mg/kg	0.07	-	0.11	0.05	-

Table 4-8: Sediment Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit [dry wt.]	AB07DA0440	AB07DA0440-A[(a)]	FR-1[(b)]	WAC-1	WAC-1-A[(a)]
		17-Oct-18	17-Oct-18	15-Oct-18	16-Oct-18	16-Oct-18
Molybdenum	mg/kg	<0.4	-	<0.4	<0.4	-
Nickel	mg/kg	1	-	2	1	-
Potassium	mg/kg	89	-	38	37	-
Selenium	mg/kg	<0.5	-	<0.5	<0.5	-
Silver	mg/kg	<0.2	-	<0.2	<0.2	-
Sodium	mg/kg	<50	-	<50	<50	-
Strontium	mg/kg	<10	-	<10	<10	-
Thallium	mg/kg	<0.1	-	<0.1	<0.1	-
Titanium	mg/kg	29	-	38	14	-
Uranium	mg/kg	<0.2	-	<0.2	<0.2	-
Vanadium	mg/kg	3	-	4	2	-
Zinc	mg/kg	<10	-	<10	<10	-
Target PAHs and Alkylated PAHs						
Acenaphthene	mg/kg	<0.0005	-	<0.005	<0.0005	-
C1 substituted acenaphthene	mg/kg	<0.005	-	<0.005	<0.005	-
Acenaphthylene	mg/kg	<0.0005	-	<0.005	<0.0005	-
Anthracene	mg/kg	0.002	-	<0.005	0.001	-
Dibenzo(a,h)anthracene	mg/kg	<0.001	-	<0.01	<0.001	-
Benzo(a)anthracene	mg/kg	<0.0005	-	<0.005	<0.0005	-
Benzo(c)phenanthrene	mg/kg	<0.005	-	<0.05	<0.005	-
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	<0.005	-	0.270	<0.005	-
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	0.015	-	0.410	0.009	-
Biphenyl	mg/kg	<0.005	-	<0.005	<0.005	-
C1 substituted biphenyl	mg/kg	<0.005	-	<0.005	<0.005	-
C2 substituted biphenyl	mg/kg	<0.005	-	<0.005	<0.005	-
Chrysene	mg/kg	<0.0005	-	<0.005	<0.0005	-
C1 substituted benzo(a)anthracene/chrysene	mg/kg	<0.005	-	0.250	<0.005	-
C2 substituted benzo(a)anthracene/chrysene	mg/kg	0.016	-	1.3	0.013	-
C3 substituted benzo(a)anthracene/chrysene	mg/kg	0.025	-	0.980	0.012	-
C4 substituted benzo(a)anthracene/chrysene	mg/kg	0.009	-	0.290	<0.005	-
Dibenzothiophene	mg/kg	<0.005	-	<0.005	<0.005	-
C1 substituted dibenzothiophene	mg/kg	<0.005	-	<0.005	<0.005	-
C2 substituted dibenzothiophene	mg/kg	0.016	-	0.250	0.011	-

Table 4-8: Sediment Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit [dry wt.]	AB07DA0440	AB07DA0440-A[a]	FR-1[b]	WAC-1	WAC-1-A[a]
		17-Oct-18	17-Oct-18	15-Oct-18	16-Oct-18	16-Oct-18
C3 substituted dibenzothiophene	mg/kg	0.012	-	0.540	0.011	-
C4 substituted dibenzothiophene	mg/kg	<0.005	-	0.870	<0.005	-
Fluoranthene	mg/kg	<0.0005	-	<0.005	<0.0005	-
Benzo(b&j)fluoranthene	mg/kg	0.0016	-	0.0430	0.0015	-
Benzo(k)fluoranthene	mg/kg	<0.0005	-	<0.005	<0.0005	-
Fluorene	mg/kg	0.0011	-	<0.005	<0.0005	-
C1 substituted fluorene	mg/kg	<0.005	-	0.030	<0.005	-
C2 substituted fluorene	mg/kg	<0.005	-	0.052	<0.005	-
C3 substituted fluorene	mg/kg	0.025	-	0.290	<0.005	-
Naphthalene	mg/kg	<0.0005	-	<0.005	<0.0005	-
1-Methylnaphthalene	mg/kg	<0.005	-	<0.005	<0.005	-
2-Methylnaphthalene	mg/kg	<0.005	-	<0.05	<0.005	-
C1 substituted naphthalene	mg/kg	<0.005	-	<0.005	<0.005	-
C2 substituted naphthalene	mg/kg	0.022	-	0.048	0.013	-
C3 substituted naphthalene	mg/kg	<0.005	-	0.022	<0.005	-
C4 substituted naphthalene	mg/kg	<0.005	-	0.100	<0.005	-
Perylene	mg/kg	0.024	-	0.052	<0.005	-
Benzo(g,h,i)perylene	mg/kg	<0.001	-	0.029	<0.001	-
Phenanthrene	mg/kg	0.0011	-	<0.005	<0.0005	-
C1 substituted phenanthrene/anthracene	mg/kg	<0.005	-	0.026	<0.005	-
C2 substituted phenanthrene/anthracene	mg/kg	<0.005	-	0.140	<0.005	-
C3 substituted phenanthrene/anthracene	mg/kg	0.021	-	0.520	0.014	-
C4 substituted phenanthrene/anthracene	mg/kg	0.031	-	0.930	0.020	-
Pyrene	mg/kg	0.0016	-	0.0720	0.0007	-
C1 substituted fluoranthene/pyrene	mg/kg	<0.005	-	0.290	<0.005	-
C2 substituted fluoranthene/pyrene	mg/kg	0.092	-	1.0	0.013	-
C3 substituted fluoranthene/pyrene	mg/kg	0.110	-	3.2	0.032	-
C4 substituted fluoranthene/pyrene	mg/kg	0.051	-	2.3	0.023	-
Indeno(1,2,3-cd)pyrene	mg/kg	<0.001	-	0.015	<0.001	-
Benzo(a)pyrene	mg/kg	<0.0005	-	0.0280	<0.0005	-
Benzo(e)pyrene	mg/kg	<0.005	-	0.067	<0.005	-
Retene	mg/kg	0.034	-	0.017	0.019	-

Table 4-8: Sediment Quality Data for Watercourse Monitoring Stations, 2018

Parameter	Unit [dry wt.]	AB07DA0440	AB07DA0440-A[a]	FR-1[b]	WAC-1	WAC-1-A[a]
		17-Oct-18	17-Oct-18	15-Oct-18	16-Oct-18	16-Oct-18
PANHs						
Acridine	mg/kg	<0.01	-	<0.1	<0.01	-
Quinoline	mg/kg	<0.01	-	<0.1	<0.01	-

[a] Results were collected at the same location and time as AB07DA0440 or WAC-1 during the October 2018 program, but were collected using the methanol vial method, rather than the collection method using unpreserved soil jars for sampling of total volatile and extractable hydrocarbons (i.e., F1/BTEX). Two sampling methods were used to allow for comparison between the historical (i.e., soil jar) and updated (i.e., methanol vial) sampling methods.

[b] Sample availability was limited at Station FR-1 in the fall program; therefore, only the unpreserved soil jar sampling method was used for the collection of total volatile and extractable hydrocarbons (i.e., F1/BTEX).

Note: dry wt. = dry weight; < = less than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

4.6.1.3 *Sediment Toxicity*

Sediment toxicity test samples were collected in 2018 at two watercourse monitoring stations located downstream of the Kearl area: Station AB07DA0440 (Muskeg River) and Station WAC-1 (Wapasu Creek). The 2018 sediment toxicity test results show that survival of *Chironomus dilutus* and *Hyalella azteca* was approximately equal to that of the laboratory control at both stations, indicating no adverse effect on survival of test organisms (Table 4-9). One exception was *Chironomus dilutes* at Station AB07DA0440, which was significantly lower than the control. Growth of *Chironomus dilutus* and *Hyalella azteca* was generally higher relative to the control at both stations, but no significant differences were detected from the control.

Table 4-9: Sediment Toxicity Results for Watercourse Monitoring Stations, 2018

Location	Test and Indicator	Mean Survival ± SD (% of control)	Mean Growth ± SD (% of control)
Muskeg River – Station AB07DA0440	*Chironomus dilutus*: 10-d Growth and Survival Test	86 ± 22[a]	132 ± 24
	Hyalella azteca: 14-d Growth and Survival Test	102 ± 0	213 ± 50
Wapasu Creek – Station WAC-1	*Chironomus dilutus*: 10-d Growth and Survival Test	92 ± 11	105 ± 6
	Hyalella azteca: 14-d Growth and Survival Test	94 ± 8	188 ± 38

Note: SD = standard deviation; d = day.

(a) Statistically significant decrease relative to the control.

4.6.2 Waterbody Monitoring Stations

4.6.2.1 *Water Quality*

Field and analytical water quality data from the 2018 monitoring program for the two waterbody monitoring stations that were sampled are summarized in Table 4-10.

Kearl Lake (Station KEL-1) was well oxygenated (7.6 mg/L or higher) in spring (May) and fall (September) 2018, but low (2.9 mg/L) under-ice in the late winter (March). The winter dissolved oxygen level was below the GOA (2018) guideline, as is typical for this shallow lake. The majority of laboratory measured parameters at Station KEL-1 in May and September were within the ranges observed in previous years (Golder 2013a, 2014, 2015, 2017a, 2017b), with the exception of dissolved phosphorus and total zinc in May and total titanium in September; these parameters were measured at concentrations higher than the historical Kearl Lake data. At Station KEL-1 in March, more parameters were measured outside the historical range compared to the other months, including specific conductivity, hardness, total alkalinity, total dissolved solids, bicarbonate, dissolved calcium, magnesium, potassium, sodium, barium, lithium, manganese, and strontium, and total manganese; these parameters were all measured at concentrations higher than the historical data. Concentrations of metals were generally higher in winter compared to spring in 2018 at Station KEL-1. The higher concentrations in winter were likely due to cryo-concentration, which is the increase in the concentration of dissolved solids as a result of exclusion during ice formation (EMAN-North 2005), and potentially the release of dissolved metals from anoxic bottom sediments. Carbonate, sulphate, nitrite, naphthenic acids, total recoverable hydrocarbons, total and dissolved cadmium, thallium, vanadium, total methyl mercury, and dissolved beryllium, chromium, silver, and titanium concentrations were below DLs in all samples.

Muskeg Lake (Station NNL-1) was well-oxygenated (8.2 mg/L or higher) in spring (May) and fall (September), and lower (6.0 mg/L) during the winter (March). The dissolved oxygen concentration measured in winter was lower than the historical range at Station NNL-1. Muskeg Lake was slightly alkaline and within the historical field pH ranges for both Muskeg and Kearl lakes. Concentrations of conventional parameters were generally within the historical range measured in previous programs at Station NNL-1, with the exception of total alkalinity in March, which was higher than the historical range, and hardness in September, which was lower than the historical range. Colour measured at Station NNL-1 was lower than what was measured at Station KEL-1 for all samples, and TOC was also generally lower at Station NNL-1 than Station KEL-1 (i.e., in May and September). Total suspended solids concentration was below the DL in Station NNL-1 in September but was measured at higher concentrations than Station KEL-1 in both March and May. Concentrations of TDS at Station NNL-1 were within the range measured in previous years and were similar between Muskeg and Kearl lakes. Major ions were generally within the historical range at Station NNL-1, except for sodium in March, which was higher than the historical range, and magnesium and sulphate in September, which were lower than the historical range. Sulphate concentrations in Muskeg Lake were higher than those in Kearl Lake in 2018 for all samples.

Nutrient concentrations in Muskeg Lake were within the ranges measured in previous years and similar to those in Kearl Lake, with the exception of nitrate and nitrate+nitrite in March and total Kjeldahl nitrogen in September. Nitrate and nitrate+nitrite concentrations were higher at Station NNL-1 in March 2018 compared to the historical range and compared to Station KEL-1 concentrations in 2018. Concentrations of total Kjeldahl nitrogen measured in September at Station NNL-1 were within the historical range but were lower than concentrations measured at Station KEL-1 in 2018.

Concentrations of metals in Muskeg Lake were generally within the range of concentrations documented by Golder (2013a, 2014, 2015, 2017a, 2017b) in previous years, with the following exceptions:

- total aluminum, arsenic, boron, chromium, cobalt, titanium, and vanadium in March, and total chromium in May were higher than in previous years;
- dissolved arsenic and boron in March, and dissolved chromium in May, were higher than in previous years;
- total molybdenum, and uranium in May, and total uranium in September were lower than in previous years; and
- dissolved aluminum and mercury in March, dissolved lithium, manganese and uranium in May, and dissolved copper, molybdenum, nickel and uranium in September, were lower than in previous years.

In general, metal concentrations at Station NNL-1 were higher than the historical concentration range measured in Muskeg Lake in March and lower than the historical range in May and September. This pattern is similar to the pattern observed for concentrations of metals measured in Kearl Lake (i.e., higher in March than in May and September). The higher concentrations in winter were likely also due to cryo-concentration (EMAN-North 2005), or potentially the release of dissolved metals from anoxic bottom sediments. Concentrations of most metals were higher in Muskeg Lake compared to Kearl Lake in 2018, such as antimony, arsenic, barium, copper, molybdenum, nickel, thallium, uranium, and vanadium. Concentrations of iron, manganese, mercury and zinc were lower in Muskeg Lake than Kearl Lake in 2018 in at least one season. Some metal parameters, however, such as beryllium, cadmium, methyl mercury, silver, and strontium, were measured at concentrations similar to Kearl Lake in 2018.

Concentrations of general organics were similar between Muskeg Lake and Kearl Lake. Naphthenic acids and total recoverable hydrocarbons were below detection in all Muskeg Lake samples in 2018. Phenol concentrations were measured within the historical range for all Muskeg Lake samples, except the September sample, where phenol concentration was higher than the historical range. Concentrations of PAHs and PANHs in Muskeg Lake were generally below detection, and those that were detected were not outside the historical range.

Table 4-10: Water Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit	KEL-1			NNL-1		
		07-Mar-18	28-May-18	02-Sep-18	06-Mar-18	28-May-18	02-Sep-18
Field Measured							
pH	-	7.0	8.5	8.0	7.9	8.4	8.1
Specific conductivity	µS/cm	287	214	201	231	274	253
Temperature	°C	1.2	16.5	9.4	0.4	16.1	11.0
Dissolved oxygen	mg/L	2.9	7.6	12.1	6.0	8.2	10.2
Conventional Parameters							
pH[(a)]	-	8.0	8.2	8.1	8.2	8.2	8.3
Specific conductivity	µS/cm	330	210	220	350	270	270
Hardness, as $CaCO_3$	mg/L	170	99	94	170	140	120
Total alkalinity, as $CaCO_3$	mg/L	170	100	100	160	140	130
Total dissolved solids	mg/L	250	160	150	210	200	200
Total suspended solids	mg/L	<1	2	1	5	3	<1
Total organic carbon	mg/L	30	20	23	21	18	19
Dissolved organic carbon	mg/L	31	19	22	20	18	19
Colour	TCU	49	24	28	15	11	13
Major Ions							
Bicarbonate	mg/L	200	130	130	190	170	150
Calcium	mg/L	43	24	23	47	37	35
Carbonate	mg/L	<1	<1	<1	<1	<1	<1
Chloride	mg/L	3	2	2	2	2	2
Magnesium	mg/L	14	8.1	8.2	13	9.5	9.0
Potassium	mg/L	2.1	1.3	1.0	1.9	1.4	1.4
Sodium	mg/L	17	11	11	13	10	10
Sulphate	mg/L	<1	<1	<1	18	12	10
Sulphide	mg/L	0.0120	0.0025	<0.0019	<0.0019	<0.0019	0.0023
Nutrients and Biological Indicators							
Nitrate	mg-N/L	0.03	<0.01	<0.01	0.20	<0.01	<0.01
Nitrate + nitrite	mg-N/L	0.027	<0.014	<0.014	0.200	<0.014	<0.014
Nitrite	mg-N/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen - ammonia	mg-N/L	0.450	0.017	0.022	0.045	0.032	0.024
Nitrogen - Kjeldahl	mg-N/L	1.9	0.90	1.1	1.00	1.1	0.81
Phosphorus, total	mg-P/L	0.013	0.032	0.045	0.019	0.031	0.024
Phosphorus, dissolved	mg-P/L	0.002	0.031	0.003	0.004	0.025	0.003

Table 4-10: Water Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit	KEL-1			NNL-1		
		07-Mar-18	28-May-18	02-Sep-18	06-Mar-18	28-May-18	02-Sep-18
Biochemical oxygen demand	mg/L	<2	<2	3	<2	<2	<2
General Organics							
Naphthenic acids	mg/L	<1	<1	<1	<1	<1	<1
Phenol	mg/L	0.003	<0.002	0.008	0.005	0.004	0.008
Total recoverable hydrocarbons	mg/L	<2	<2	<2	<2	<2	<2
Metals (Total)							
Aluminum	µg/L	5.2	18	33	67	26	30
Antimony	µg/L	0.03	0.04	0.03	0.05	0.05	0.03
Arsenic	µg/L	0.33	0.28	0.32	0.53	0.37	0.43
Barium	µg/L	31	16	21	61	40	40
Beryllium	µg/L	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	45	38	41	55	39	39
Cadmium	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	<0.1	0.1	<0.1	0.2	0.2	<0.1
Cobalt	µg/L	0.044	0.035	0.035	0.099	0.039	0.058
Copper	µg/L	0.22	0.15	<0.1	0.57	0.40	0.34
Iron	µg/L	920	57	63	100	35	69
Lead	µg/L	0.024	0.039	0.200	0.096	0.030	0.043
Lithium	µg/L	9.4	7.2	8.0	10	7.1	7.5
Manganese	µg/L	240	36	18	7.8	7.0	23
Mercury	µg/L	0.00069[(a)]	0.00080	0.00088	0.00076[(a)]	0.00067	0.00065
Methyl Mercury	µg/L	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Molybdenum	µg/L	0.08	0.06	0.06	0.39	0.25	0.26
Nickel	µg/L	0.20	0.20	0.17	1.2	0.76	0.64
Selenium	µg/L	0.04	<0.04	<0.04	0.05	<0.04	<0.04
Silver	µg/L	<0.01	<0.005	0.014	<0.005	<0.01	<0.01
Strontium	µg/L	100	74	75	99	78	79
Thallium	µg/L	<0.002	<0.002	<0.002	0.006	0.004	0.004
Titanium	µg/L	<2	<0.5	2	3	<2	<2
Uranium	µg/L	0.016	0.019	0.011	0.480	0.310	0.270
Vanadium	µg/L	<0.2	<0.2	<0.2	0.4	0.2	<0.2
Zinc	µg/L	3.1	21	2.2	2.7	1.9	1.3

Table 4-10: Water Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit	KEL-1			NNL-1		
		07-Mar-18	28-May-18	02-Sep-18	06-Mar-18	28-May-18	02-Sep-18
Metals (Dissolved)							
Aluminum	µg/L	1.2	4.3	2.6	1.1	4.3	3.0
Antimony	µg/L	0.03	0.04	0.02	0.04	0.05	0.03
Arsenic	µg/L	0.43	0.27	0.28	0.54	0.34	0.40
Barium	µg/L	38	15	19	59	40	38
Beryllium	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	56	37	40	58	40	40
Cadmium	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
Cobalt	µg/L	0.047	0.018	0.025	0.044	0.017	0.028
Copper	µg/L	<0.05	0.08	0.06	0.47	0.31	0.26
Iron	µg/L	640	13	17	4	2	9
Lead	µg/L	<0.005	<0.005	0.007	0.008	<0.005	0.010
Lithium	µg/L	12	7.2	8.3	10	7.2	8.1
Manganese	µg/L	190	0.16	0.18	1.20	0.06	0.07
Mercury	µg/L	0.00023[a]	0.00030[a]	0.00042	<0.00011[a]	0.00034	0.00026
Molybdenum	µg/L	0.09	0.06	0.06	0.41	0.27	0.23
Nickel	µg/L	0.18	0.14	0.15	1.1	0.68	0.56
Selenium	µg/L	0.04	<0.04	<0.04	0.06	<0.04	<0.04
Silver	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	µg/L	130	70	73	110	82	78
Thallium	µg/L	<0.002	<0.002	<0.002	0.004	0.002	0.002
Titanium	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	µg/L	0.021	0.019	0.008	0.480	0.330	0.240
Vanadium	µg/L	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
Zinc	µg/L	2.7	2.6	0.8	1.9	0.9	0.7
Target PAHs and Alkylated PAHs							
Acenaphthene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted acenaphthene	µg/L	-	-	-	<0.005	<0.005	<0.005
Acenaphthylene	µg/L	-	-	-	<0.005	<0.005	<0.005
Anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005
Dibenzo(a,h)anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(a)anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005

Table 4-10: Water Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit	KEL-1			NNL-1		
		07-Mar-18	28-May-18	02-Sep-18	06-Mar-18	28-May-18	02-Sep-18
Benzo(c)phenanthrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
Biphenyl	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted biphenyl	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted biphenyl	µg/L	-	-	-	<0.005	<0.005	<0.005
Chrysene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	<0.005	<0.005	<0.005
C3 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	<0.005	<0.005	<0.005
C4 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	<0.005	<0.005	<0.005
Dibenzothiophene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted dibenzothiophene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted dibenzothiophene	µg/L	-	-	-	<0.005	<0.005	<0.005
C3 substituted dibenzothiophene	µg/L	-	-	-	<0.005	<0.005	<0.005
C4 substituted dibenzothiophene	µg/L	-	-	-	<0.005	<0.005	<0.005
Fluoranthene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(b&j)fluoranthene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(k)fluoranthene	µg/L	-	-	-	<0.005	<0.005	<0.005
Indeno(1,2,3-cd)fluoranthene	ug/L	-	-	-	<0.005	<0.005	<0.005
Fluorene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted fluorene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted fluorene	µg/L	-	-	-	<0.005	<0.005	<0.005
C3 substituted fluorene	µg/L	-	-	-	<0.005	<0.005	<0.005
Naphthalene	µg/L	-	-	-	0.011	0.022	0.014
1-Methylnaphthalene	µg/L	-	-	-	<0.005	0.007	<0.005
2-Methylnaphthalene	µg/L	-	-	-	0.006	0.013	0.007
C1 substituted naphthalene	µg/L	-	-	-	0.009	0.021	0.011
C2 substituted naphthalene	µg/L	-	-	-	0.007	0.007	0.005
C3 substituted naphthalene	µg/L	-	-	-	0.010	0.007	<0.005
C4 substituted naphthalene	µg/L	-	-	-	0.007	<0.005	<0.005
Perylene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(g,h,i)perylene	µg/L	-	-	-	<0.005	<0.005	<0.005

Table 4-10: Water Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit	KEL-1			NNL-1		
		07-Mar-18	28-May-18	02-Sep-18	06-Mar-18	28-May-18	02-Sep-18
Phenanthrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted phenanthrene/anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted phenanthrene/anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005
C3 substituted phenanthrene/anthracene	µg/L	-	-	-	0.006	<0.005	<0.005
C4 substituted phenanthrene/anthracene	µg/L	-	-	-	<0.005	<0.005	<0.005
Pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C1 substituted fluoranthene/pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C2 substituted fluoranthene/pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C3 substituted fluoranthene/pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
C4 substituted fluoranthene/pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
Indeno(1,2,3-cd)pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(a)pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
Benzo(e)pyrene	µg/L	-	-	-	<0.005	<0.005	<0.005
Retene	µg/L	-	-	-	<0.005	<0.005	<0.005
PANHs							
Acridine	µg/L	-	-	-	<0.005	<0.005	<0.005
Quinoline	µg/L	-	-	-	0.012	0.006	0.023

(a) Parameter analzed past the recommended hold time.

- = not applicable or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

4.6.2.2 Sediment Quality

Analytical results for sediment quality samples collected from both waterbody monitoring stations sampled in 2018 (i.e., Muskeg Lake [Station NNL-1] and Kearl Lake [Station KEL-1]) are presented in Table 4-11. Sand was the dominant fraction of inorganic bottom sediments in both lakes. At Station NNL-1, TOC content was low (2.4%), which is unusual for natural lake sediments in the region. However, Muskeg Lake is recently constructed and in the early stages of development and it is expected that over time TOC will increase to values typical of natural lakes, such as those found in Kearl Lake (37%). TOC and total carbon measured in Muskeg Lake in 2018 were both higher than the historical range, which may represent the start of the expected increasing trend in carbon in Muskeg Lake sediments.

Concentrations of metals were generally low at Station NNL-1 and similar to those observed previously; however, some metal concentrations, including arsenic, calcium, cobalt, lead, magnesium, manganese, and molybdenum were somewhat higher (by 20% or less) than the maximum concentrations observed since monitoring began in 2013. Concentrations of metals in sediment were generally higher at Station KEL-1 compared to Station NNL-1, with the exception of iron, manganese, titanium and vanadium, which were higher at Station NNL-1.

Concentrations of hydrocarbons, PAHs and PANHs at Station NNL-1 were within the range of concentrations observed in previous years with the exception of the following PAHs: chrysene, C2 substituted benzofluoranthenes/benzopyrenes, C2 substituted biphenyls, C2, C3 and C4 substituted dibenzothiophenes, C2 and C3 substituted fluoranthenes/pyrenes, and C3 and C4 substituted phenanthrenes/anthracenes, which were higher than the historical range of concentrations for Station NNL-1 by 2% to 75% (Golder 2013a, 2014, 2015, 2017a, 2017b). Concentrations of hydrocarbons, PAHs and PANHs were typically lower at Station KEL-1, with the exception of fluoranthene, fluorene, C2 substituted naphthalene, and phenanthrene.

Table 4-11: Sediment Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit [dry wt.]	KEL-1	NNL-1
		02-Sep-18	02-Sep-18
Particle Size			
Sand content	%	68	62
Silt content	%	28	27
Clay content	%	3.5	11
Moisture content	%	93	26
Carbon Content			
Total inorganic carbon	%	0.44	0.89
Total organic carbon	%	37	2.4
Total carbon	%	37	3.3
Organics			
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	<120	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	42	300
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	350	2,600
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	<98	1,200
Total petroleum hydrocarbons	mg/kg	<650	7,000
Metals (Total)			
Aluminum	mg/kg	3,400	3,000
Antimony	mg/kg	<0.5	<0.5
Arsenic	mg/kg	2	1
Barium	mg/kg	59	29
Beryllium	mg/kg	<0.4	<0.4

Table 4-11: Sediment Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit [dry wt.]	KEL-1	NNL-1
		02-Sep-18	02-Sep-18
Boron	mg/kg	20	5
Cadmium	mg/kg	0.43	<0.05
Calcium	mg/kg	13,000	39,000
Chromium	mg/kg	31	8
Cobalt	mg/kg	3.1	2.7
Copper	mg/kg	9	4
Iron	mg/kg	6,300	7,000
Lead	mg/kg	3.7	3.3
Lithium	mg/kg	<10	<10
Magnesium	mg/kg	1,800	11,000
Manganese	mg/kg	120	140
Mercury	mg/kg	0.08	<0.05
Molybdenum	mg/kg	1.4	0.6
Nickel	mg/kg	23	9
Potassium	mg/kg	400	600
Selenium	mg/kg	0.8	<0.5
Silver	mg/kg	<0.2	<0.2
Sodium	mg/kg	250	56
Strontium	mg/kg	38	27
Thallium	mg/kg	<0.1	<0.1
Titanium	mg/kg	37	56
Uranium	mg/kg	0.6	0.5
Vanadium	mg/kg	9	11
Zinc	mg/kg	76	11
Target PAHs and Alkylated PAHs			
Acenaphthene	mg/kg	<0.0066	<0.005
C1 substituted acenaphthene	mg/kg	<0.067	<0.005
Acenaphthylene	mg/kg	<0.0066	<0.005
Anthracene	mg/kg	<0.0066	<0.005
Dibenzo(a,h)anthracene	mg/kg	<0.013	0.013
Benzo(a)anthracene	mg/kg	<0.0066	0.0100
Benzo(c)phenanthrene	mg/kg	<0.066	<0.05
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	<0.067	0.380
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	<0.067	0.460
Biphenyl	mg/kg	<0.067	<0.005
C1 substituted biphenyl	mg/kg	<0.067	<0.005
C2 substituted biphenyl	mg/kg	<0.067	0.025
Chrysene	mg/kg	<0.0066	0.0079
C1 substituted benzo(a)anthracene/chrysene	mg/kg	<0.067	0.380
C2 substituted benzo(a)anthracene/chrysene	mg/kg	<0.067	1.9
C3 substituted benzo(a)anthracene/chrysene	mg/kg	<0.067	1.1
C4 substituted benzo(a)anthracene/chrysene	mg/kg	<0.067	0.320
Dibenzothiophene	mg/kg	<0.067	<0.005
C1 substituted dibenzothiophene	mg/kg	<0.067	0.014
C2 substituted dibenzothiophene	mg/kg	<0.067	0.600
C3 substituted dibenzothiophene	mg/kg	<0.067	0.990

Table 4-11: Sediment Quality Data for Waterbody Monitoring Stations, 2018

Parameter	Unit [dry wt.]	KEL-1	NNL-1
		02-Sep-18	02-Sep-18
C4 substituted dibenzothiophene	mg/kg	<0.067	1.8
Fluoranthene	mg/kg	0.0081	0.0067
Benzo(b&j)fluoranthene	mg/kg	<0.0066	0.0450
Benzo(k)fluoranthene	mg/kg	<0.0066	0.0074
Fluorene	mg/kg	0.008	<0.005
C1 substituted fluorene	mg/kg	<0.067	0.016
C2 substituted fluorene	mg/kg	<0.067	0.099
C3 substituted fluorene	mg/kg	<0.067	0.500
Naphthalene	mg/kg	<0.0066	<0.005
1-Methylnaphthalene	mg/kg	<0.067	<0.005
2-Methylnaphthalene	mg/kg	<0.066	<0.05
C1 substituted naphthalene	mg/kg	<0.067	<0.005
C2 substituted naphthalene	mg/kg	0.260	0.051
C3 substituted naphthalene	mg/kg	<0.067	0.053
C4 substituted naphthalene	mg/kg	<0.067	0.170
Perylene	mg/kg	<0.066	0.064
Benzo(g,h,i)perylene	mg/kg	<0.013	0.026
Phenanthrene	mg/kg	0.011	<0.005
C1 substituted phenanthrene/anthracene	mg/kg	<0.067	0.040
C2 substituted phenanthrene/anthracene	mg/kg	<0.067	0.220
C3 substituted phenanthrene/anthracene	mg/kg	<0.067	1.2
C4 substituted phenanthrene/anthracene	mg/kg	<0.067	1.5
Pyrene	mg/kg	<0.0066	0.0770
C1 substituted fluoranthene/pyrene	mg/kg	<0.067	0.570
C2 substituted fluoranthene/pyrene	mg/kg	<0.067	1.7
C3 substituted fluoranthene/pyrene	mg/kg	<0.067	4.9
C4 substituted fluoranthene/pyrene	mg/kg	<0.067	2.7
Indeno(1,2,3-cd)pyrene	mg/kg	<0.013	0.016
Benzo(a)pyrene	mg/kg	<0.0066	0.0290
Benzo(e)pyrene	mg/kg	<0.066	0.060
Retene	mg/kg	<0.067	0.017
PANHs			
Acridine	mg/kg	<0.13	<0.1
Quinoline	mg/kg	<0.13	<0.1

Note: dry wt. = dry weight; < = less than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

4.6.3 Quality Control

4.6.3.1 Water Quality

Concentrations of water quality parameters in the field blanks collected during the 2018 monitoring program were not notable (i.e., were below five times the DL; Appendix III, Table III-1), with the exception of total aluminum in the September field blank – the concentration of total aluminum was five times greater than the detection limit but was below the concentration of the corresponding late summer 2018 water quality field samples. The difference in total aluminum concentration between the field samples and the field blank was greater than five times the DL; therefore, field sample contamination was not suspected. Overall, the results indicate that field samples collected during 2018 sampling programs were free of contamination.

Few parameters were above the duplicate sample QC criterion in water samples collected in 2018 (Appendix III, Table III-2). No parameters were above the QC criterion in October. Of the 79 parameters analyzed (excluding pH), three parameters were above the QC criterion in March, three in May, and one in August, which represents 4%, 4%, and 1% of the total analyzed parameters, respectively. Therefore, within-station variability was rated as low and field sampling precision was rated as high for all 2018 programs.

Some field measured data were considered erroneous upon closer inspection. Field measured dissolved oxygen concentrations measured at Stations FR-1 and IYC-1 in October were invalidated due to suspected equipment malfunction.

4.6.3.2 Sediment Quality

Few parameters were above the split sample QC criteria in sediment samples collected in September and October 2018 (Appendix III, Table III-3). Of the 95 parameters analyzed, seven parameters were above the QC criteria in September, and one in October, which represents 7% and 1% of the total analyzed parameters, respectively. There were no parameters that were above the QC criteria for the additional organics analysis conducted in the October program using the new sampling and methanol preservation procedure either. Therefore, within-station variability was rated as low and field sampling precision was rated as high for 2018.

4.7 Data Summary for Watercourse Monitoring Stations

4.7.1 Guideline Comparisons

4.7.1.1 Water Quality

Concentrations of water quality parameters in the study area using data from 2006 to 2018 were compared to the relevant water quality guidelines (GOA 2018; HC 2017). Several parameters exceeded or were outside the range of the acute WQG, chronic WQG, and/or wildlife guidelines (Appendix V, Tables V-1 to V-8). Parameters with guideline exceedances were:

- field parameters: field pH and dissolved oxygen
- major ions: sulphide
- general organics: total phenolics (and/or phenol)
- total metals: chromium, selenium, cobalt, cadmium, lead, mercury, and
- dissolved aluminium and iron.

Exceedances for these parameters are summarized seasonally for each watershed below.

Firebag River Watershed

For the Firebag River watershed monitoring stations (Figure 4-1), field pH measurements were within the chronic WQG range during the baseline phase but were outside the chronic WQG range during the operational phase, primarily during summer and in some winter measurements (Appendix V, Tables V-1 and V-2). The summer field pH measurements were above the chronic WQG range, and the winter measurements were below the chronic WQG range during the operational phase (Appendix V, Table V-2). During both phases, dissolved oxygen concentrations were below the minimum acute and chronic WQGs frequently during the winter and sometimes during the summer.

Conventional parameter and major ion concentrations were below the guidelines with the exception of sulphide. Sulphide concentrations exceeded the chronic WQG in many winter, spring and summer samples during the baseline phase and in a similar number of winter and spring samples during the operational phase.

Total phenolic concentrations exceeded the chronic WQG and wildlife guideline in many winter samples, and in most spring and summer samples, during the baseline phase. Total phenolic (and phenol) concentrations exceeded the chronic WQG and wildlife guideline in many spring and fall samples and the chronic WQG was also exceeded in most summer samples during the operational phase.

Most total and dissolved metal concentrations were below guidelines in both the baseline and operational phases. During the baseline phase, total chromium concentrations exceeded the chronic WQG in some winter and spring samples and total selenium concentrations exceeded the chronic WQG in some spring samples; no total metal concentrations exceeded guidelines during the operational phase. Dissolved iron concentrations exceeded the chronic WQG in most samples in all seasons during both the baseline and operational phases.

Muskeg Creek Watershed

For the Muskeg Creek watershed monitoring stations (Figure 4-1), field pH measurements were within the chronic WQG range during the baseline phase but were occasionally above the chronic WQG range in spring and below the chronic WQG range in summer during the operational phase (Appendix V, Tables V-3 and V-4, respectively). Dissolved oxygen concentrations were above the minimum acute and chronic WQGs in the baseline phase but were below the minimum chronic and acute WQGs in most winter measurements and some spring measurements during the operational phase.

Conventional parameter and major ion concentrations were below guidelines with the exception of sulphide. Sulphide concentration exceeded the chronic WQG in all winter samples and many spring, summer, and fall samples during the baseline phase, and many winter, spring, and fall samples during the operational phase.

Total phenolic (and/or phenol) concentrations exceeded the chronic WQG and wildlife guideline in all or most samples collected in all seasons during both phases.

Most total and dissolved metal concentrations were below guidelines in both the baseline and operational phases. During the baseline phase, total chromium and cobalt concentrations exceeded the chronic WQG in most winter samples; some chromium concentrations also exceeded the chronic WQG during the fall. Total mercury concentrations exceeded the chronic WQG for most winter samples and exceeded the acute and chronic WQGs in some fall samples during the baseline phase. During the operational phase, total chromium, cobalt, and mercury concentrations exceeded the chronic WQG in some spring and fall samples, and total lead concentrations exceeded the chronic WQG in some spring samples. Dissolved aluminium concentrations exceeded the acute and chronic WQGs in most winter samples during the baseline phase, and some concentrations measured in spring and fall exceeded the chronic WQG during the operational phase. Dissolved iron concentrations exceeded the chronic WQG in all winter samples and many summer and fall samples during

the baseline phase. Dissolved iron concentration exceeded the chronic WQG for most samples in all seasons during the operational phase.

Muskeg River Watershed

For the Muskeg River watershed monitoring stations (Figure 4-1), field pH measurements were within the chronic WQG range during the baseline phase but were occasionally outside the chronic WQG range in winter, summer, and fall during the operational phase (Appendix V, Tables V-5 and V-6, respectively). Some summer field pH measurements exceeded the chronic WQG range, and most other pH measurements were below the chronic WQG range in all seasons during the operational phase. Dissolved oxygen concentrations were below the minimum acute and chronic WQGs for most winter, and many summer and fall measurements during the baseline phase. During the operational phase, dissolved oxygen concentrations were below the minimum acute and chronic WQGs for most winter, summer and fall samples, and were below the minimum chronic WQG for some spring measurements.

Conventional parameter and major ion concentrations were below guidelines with the exception of sulphide. Sulphide concentrations exceeded the chronic WQG in some winter, summer, and fall samples during the baseline phase, and most summer and fall samples and several winter and spring samples during the operational phase.

During the baseline phase, total phenolics concentrations exceeded the wildlife guideline in all or most of the winter, summer, and fall samples, and exceeded the chronic WQG in most summer and fall samples. During the operational phase, total phenolics (and/or phenol) concentrations exceeded the wildlife guideline in all or most samples in all seasons and exceeded the chronic WQG in many winter, spring, and fall, and a few summer samples.

Most total and dissolved metal concentrations were below guidelines in both the baseline and operational phases. During the baseline phase, total cadmium concentrations exceeded the chronic WQG in some summer samples. During the operational phase, total chromium and mercury concentrations exceeded the chronic WQG in a few winter samples, and mercury concentrations also exceeded the chronic WQG in a few spring samples. Dissolved iron concentrations exceeded the chronic WQG in most winter and summer samples, and many spring and fall samples during the baseline phase. Dissolved iron concentrations exceeded the chronic WQG in most summer and fall samples and many winter and spring samples.

Wapasu Creek Watershed

For the Wapasu Creek watershed monitoring station (Figure 4-1), field pH measurements were within the chronic WQG range during the baseline phase but were below the chronic WQG range for a few summer measurements during the operational phase (Appendix V, Tables V-7 and V-8, respectively). Dissolved oxygen concentrations were above the minimum acute and chronic WQGs during the baseline phase but were below the minimum acute and chronic WQGs in many winter and summer samples during the operational phase.

Conventional parameter and major ion concentrations were below guidelines with the exception of sulphide. Sulphide concentrations exceeded the chronic WQG in all or most baseline phase samples in all seasons, and many operational phase samples in all seasons.

During the baseline phase, total phenolics exceeded the chronic WQG and wildlife guideline for all or most samples in summer and fall. During the operational phase, total phenolics (and/or phenol) exceeded the chronic WQG in many winter, spring and summer samples and most fall samples, and exceeded the wildlife guideline in all or most samples in every season.

All total metal concentrations were below guidelines during both the baseline and operational phases. Dissolved iron concentrations exceeded the chronic WQG in all winter and summer samples during the baseline phase and exceeded the chronic WQG in most summer samples and many winter, spring and fall samples in the operational phase.

Summary

The number of guideline exceedances in all watersheds were similar in the baseline phase compared to the operational phase for most parameters; however, field pH was measured outside the chronic WQG more frequently in the operational phase in all watersheds. This pattern was also observed for dissolved oxygen concentrations at Muskeg and Wapasu creeks. Dissolved oxygen concentrations were below the minimum WQGs more frequently during winter and summer. This seasonal trend is expected, because dissolved oxygen cannot be replenished from contact with the atmosphere during ice-cover, and aerobic respiration by bacteria in sediments results in increased oxygen demand in summer (McNeely et al. 1979). Sulphide and total phenolics (and/or phenol) concentrations exceeded guidelines consistently in all seasons in both phases. There were no strong seasonal trends for total or dissolved metal concentrations; however, the fewest guideline exceedances were observed in summer. In general, more metal parameters exceeded guidelines in the Muskeg Creek watershed relative to other watersheds.

4.7.1.2 Sediment Quality

Most sediment parameter concentrations were below the CCME (1998) ISQG and PELs, with the exception of two metals and a number of PAHs (Appendix VI, Tables VI-1 and VI-2). During the baseline phase, one concentration of total copper (in 2009), acenaphthene (in 2007) and naphthalene (in 2006) exceeded the ISQG in the Muskeg Creek watershed at Station KEL-1. Concentrations of acenaphthene (in 2007) and chrysene (in 2006, 2007, 2009, and 2010) occasionally exceeded the ISQG in Muskeg River (Station MUR-D2) during the baseline phase. During the operational phase, one concentration of total chromium (in 2015), acenaphthene (in 2013), and fluorene (in 2013) in Wapasu Creek (Station WAC-1) and one concentration of dibenzo(a,h)anthracene (in 2011) in Muskeg River (Station MUR-D2) exceeded the ISQG. In Firebag River at Station FR-1, concentrations of acenaphthylene (in 2017), dibenzo(a,h)anthracene (in 2017), chrysene (in 2013), pyrene (in 2013, 2014, 2017, and 2018), and benzo(a)pyrene (in 2013 and 2014) also exceeded the ISQG in the operational phase. The concentrations of hydrocarbons and PAHs suggest that the sediment sample collected contained eroded oil sands in both the baseline and operational phases.

4.7.2 Temporal Trends in Water Quality

Time series plots of key water quality parameters (i.e., parameters that showed temporal trends and other selected parameters) are presented in Figures 4-2 to 4-11. Time series plots for all other parameters are provided in Appendix VII. Plots were grouped by watershed as follows:

- Firebag River (panel a; Stations ET-1, CT-1, WT-1 and FR-1);
- Muskeg River (panel b; Stations MR-2, MUR-6, AB07DA0440 and AB07DA0475);
- Muskeg Creek (panel c; Stations IYC-1, KEL-1 and MUC-1); and
- Wapasu Creek (panel d; Station WAC-1).

On these plots, a solid vertical line separates the baseline phase from the construction phase, and a dashed vertical line marks the beginning of the operational phase.

Field measured water quality parameters, conventional parameters, major ions and nutrients generally did not show temporal trends or showed only weak trends (Appendix VII). In the operational phase, field measured pH was more variable over time in Muskeg River and Muskeg Creek but did not show an overall trend (Appendix VII, Figure VII-1). No temporal trends were identified for dissolved oxygen concentrations; however, some lower concentrations were measured in the operational phase at Muskeg Creek and the construction phase at Wapasu Creek, relative to the baseline phase (Appendix VII, Figure VII-4). This pattern is due to the seasonality of dissolved oxygen concentrations and reflects the lack of winter samples collected in the baseline phase.

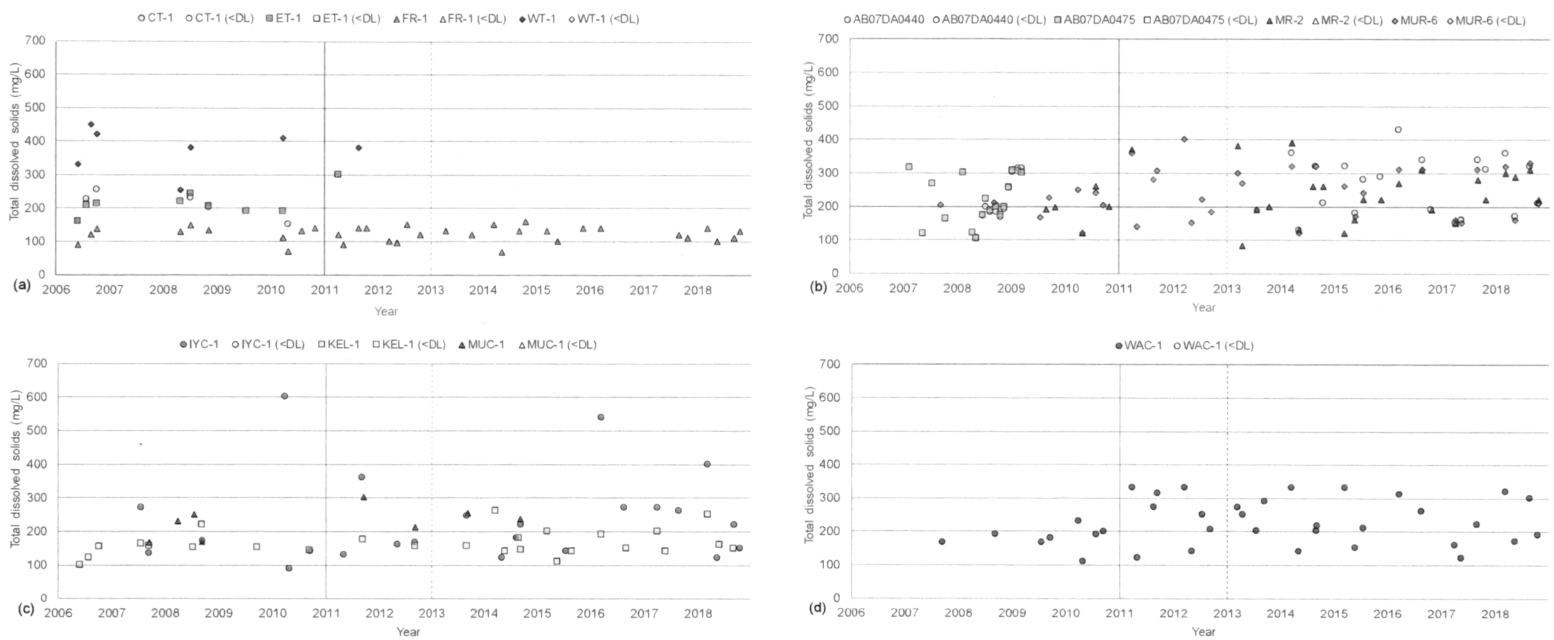
Calcium, magnesium, and chloride concentrations in Wapasu Creek varied over a wide range during the construction and operational phases (1 to 12 mg/L, 18 to 181 mg/L, and 6.4 to 28 mg/L, respectively) compared to the baseline phase (Appendix VII, Figures VII-14, VII-15, and VII-20). As calcium, magnesium, and chloride are major components of TDS, TDS concentrations also varied during the construction phase in Wapasu Creek but did not show an increasing or decreasing trend over time (Figure 4-2). In the operational phase, a wider range of concentrations in Wapasu Creek was observed for field and laboratory measured specific conductivity, hardness, total alkalinity, and bicarbonate, than during the baseline phase (Appendix VII, Figures VII-2, VII-6, VII-7, VII-8, and VII-18). Concentrations of major ions such as calcium, magnesium, and bicarbonate, influence conductivity, alkalinity, and hardness measurements, so a similar trend between all these parameters is expected (McNeely et al. 1979). The range of sulphate and sulphide concentrations was higher in Muskeg River after project operations began (Appendix VII, Figures VII-21 and VII-22).

Total ammonia, total phosphorus, and BOD concentrations were higher in Muskeg River after project operational began (Appendix VII, Figures VII-24, VII-26, and VII-28); no trends were observed for these parameters in the other three watersheds.

Four elevated total phenolics concentrations, relative to baseline concentrations, were observed at Station MR-2 in Muskeg River during the operational phase (Figure 4-3); however, an elevated concentration was also observed at Station MUR-6 in the Muskeg River during the baseline phase. Total phenolics concentrations show an overall decrease over time in all other watersheds.

Total and dissolved metals generally did not show temporal trends (Appendix VII), including metals that exceeded water quality guidelines (i.e., total chromium, selenium, cadmium, lead, mercury and dissolved aluminium), with the exception of total cobalt and dissolved iron, which appear to have increased at some stations in the Muskeg River after the construction phase (Figures 4-4 and 4-5). Concentrations of these parameters above water quality guidelines were common during the baseline phase, suggesting they are naturally above guidelines in the monitored watersheds (Section 4.7.1). In general, most metal concentrations were elevated at some point during construction and early operational phase but did not show any long-term trends.

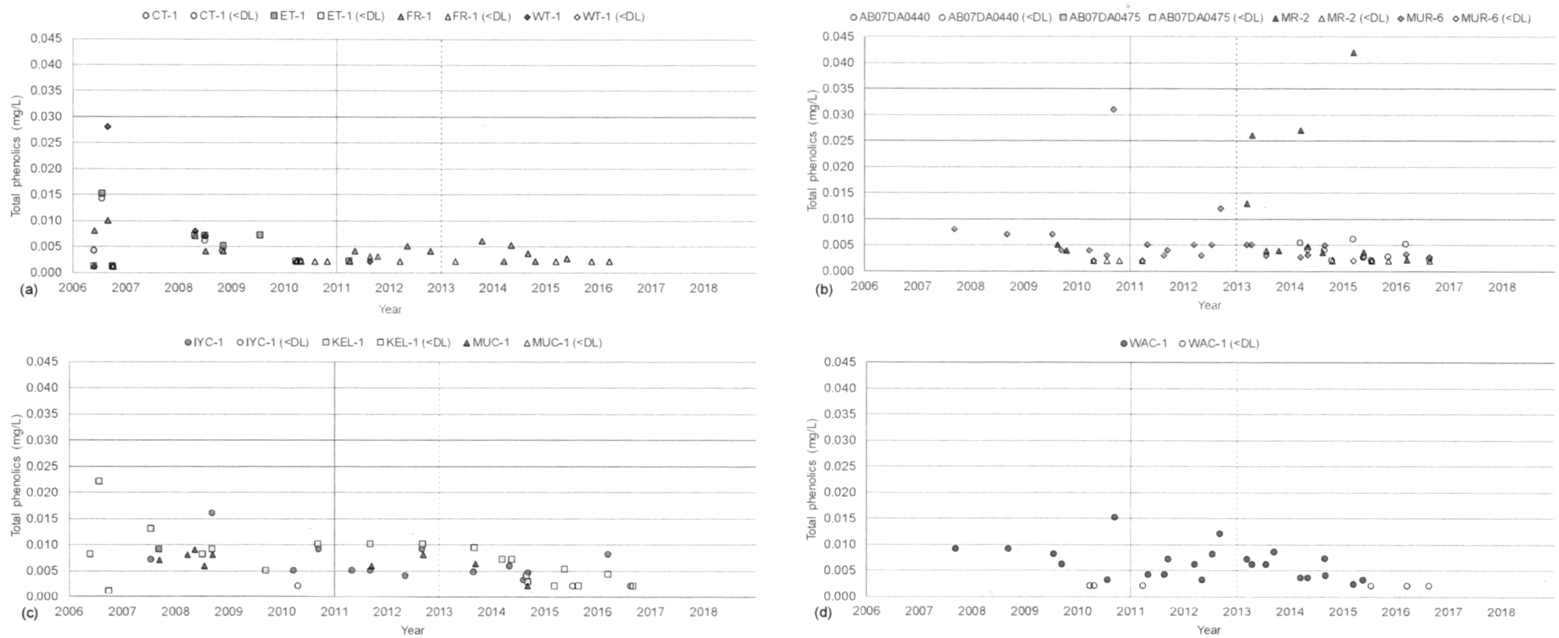
Total and dissolved arsenic concentrations appear to have increased at some stations in the Muskeg River after the construction phase (Figure 4-6; Appendix VI, Figure VII-61). Total and dissolved antimony concentrations have decreased in the Firebag River since the baseline phase (Figure 4-7; Appendix VII, Figure VII-60). During the construction and operational phases, the range of total and dissolved manganese concentrations measured at Wapasu Creek and two stations in Muskeg River (i.e., MUR-6 and MR-2) was greater than during the baseline phase (Appendix VII, Figures VII-46 and VII-72). Methyl mercury concentrations have increased in the Muskeg River over time; the range in concentrations measured during the operational phase is greater than during the baseline and construction phases (Figure 4-8). The range of total and dissolved molybdenum concentrations measured in Muskeg Creek was greater during the operational phase relative to the baseline phase at Station IYC-1 (Appendix VII, Figures VII-49 and VII-74). Total titanium and vanadium concentrations measured in Muskeg Creek have decreased in the operational phase relative to the construction and baseline phases (Figures 4-9 and 4-10); a similar pattern was observed for dissolved titanium and vanadium (Appendix VII, Figures VII-80 and VII-82). Total and dissolved zinc concentrations measured in the Firebag River have decreased in the construction and operational phases relative to the baseline phase (Figure 4-11; Appendix VII, Figure VII-83).



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

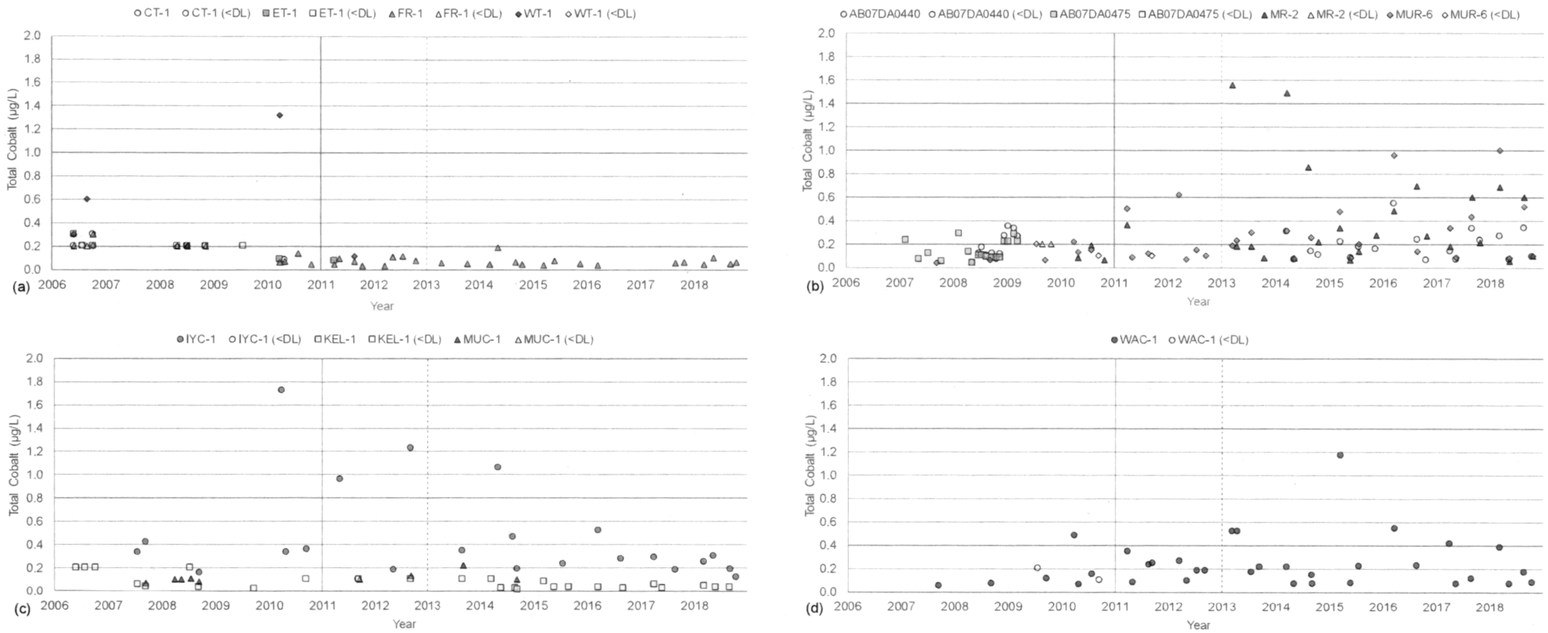
Figure 4-2: Time Series Plots of Total Dissolved Solids



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

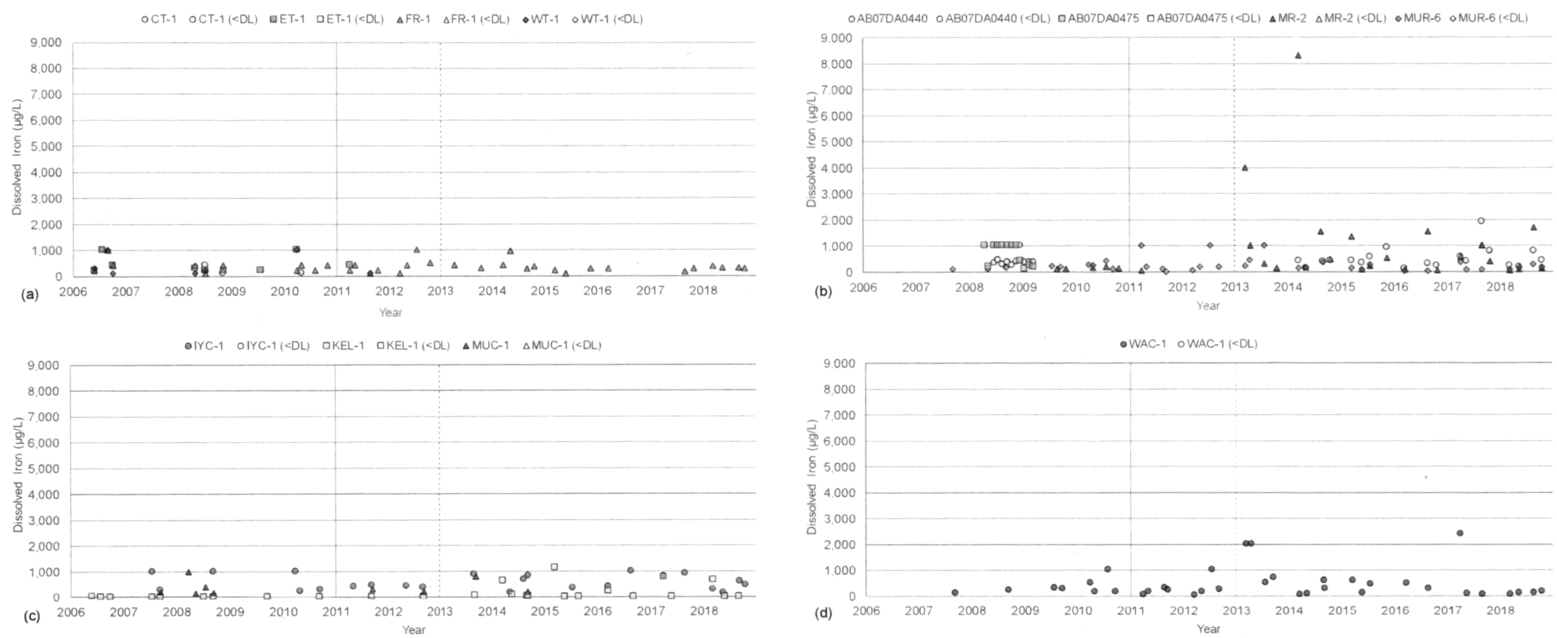
Figure 4-3: Time Series Plots of Total Phenolics



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

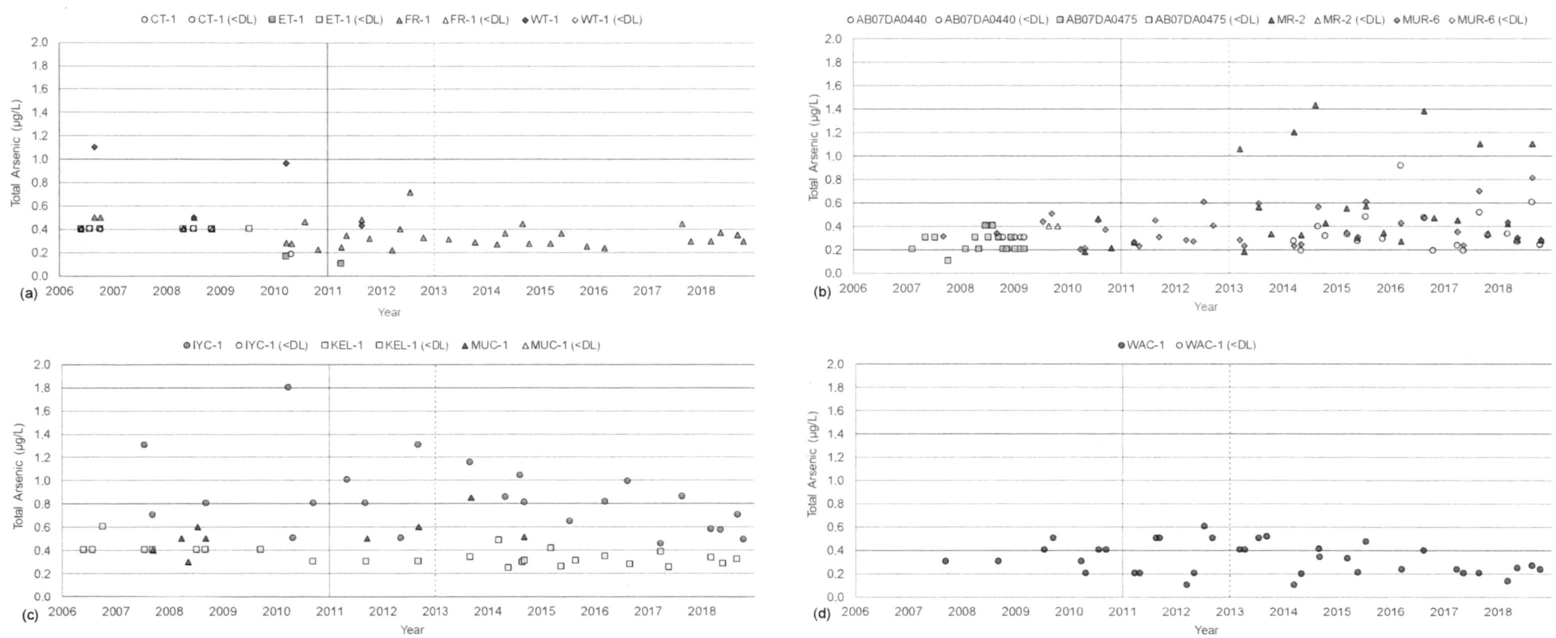
Figure 4-4: Time Series Plots of Total Cobalt



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

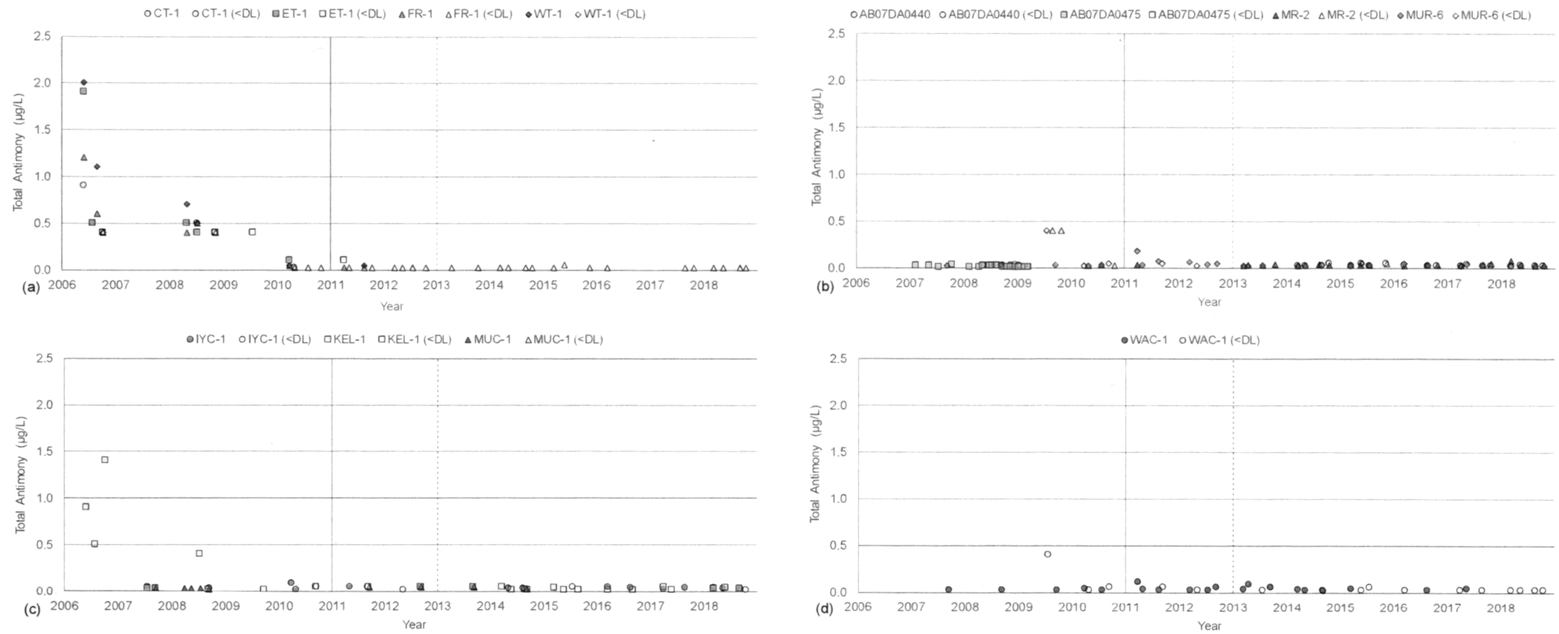
Figure 4-5: **Time Series Plots of Dissolved Iron**



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

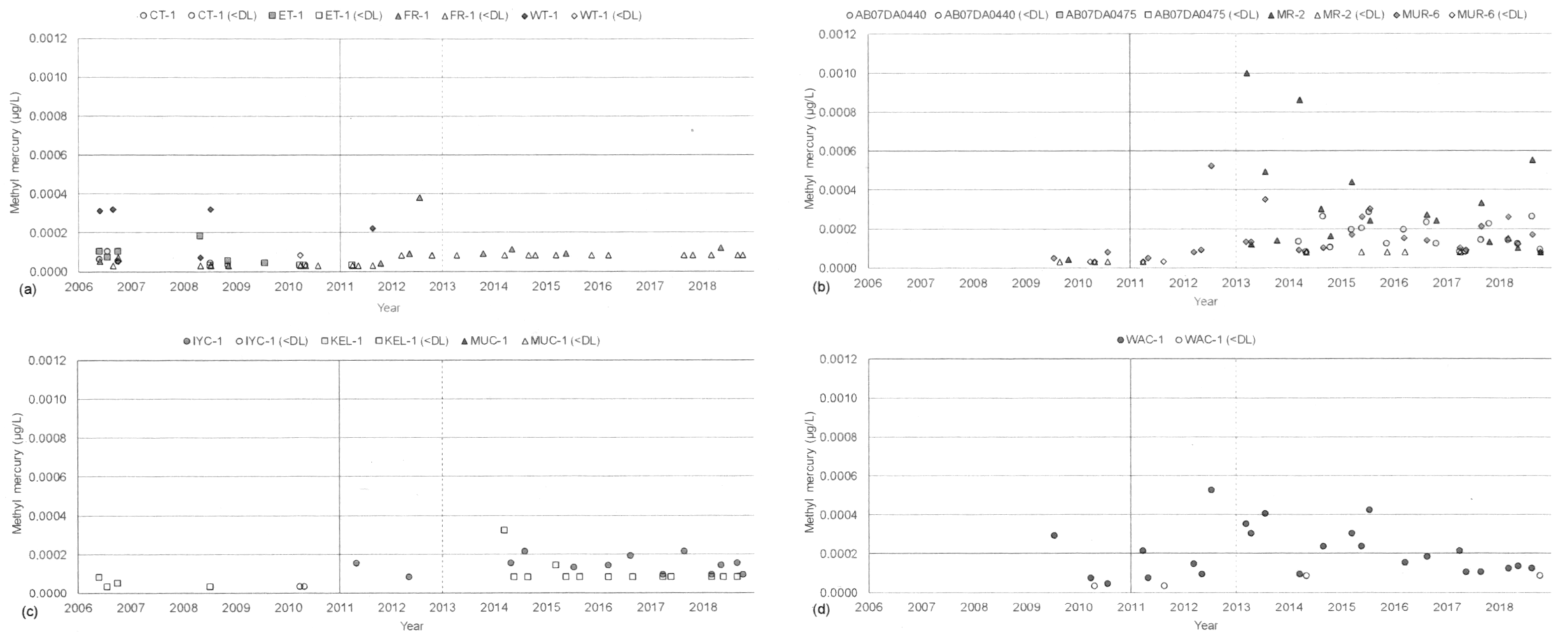
Figure 4-6: Time Series Plots of Total Arsenic



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

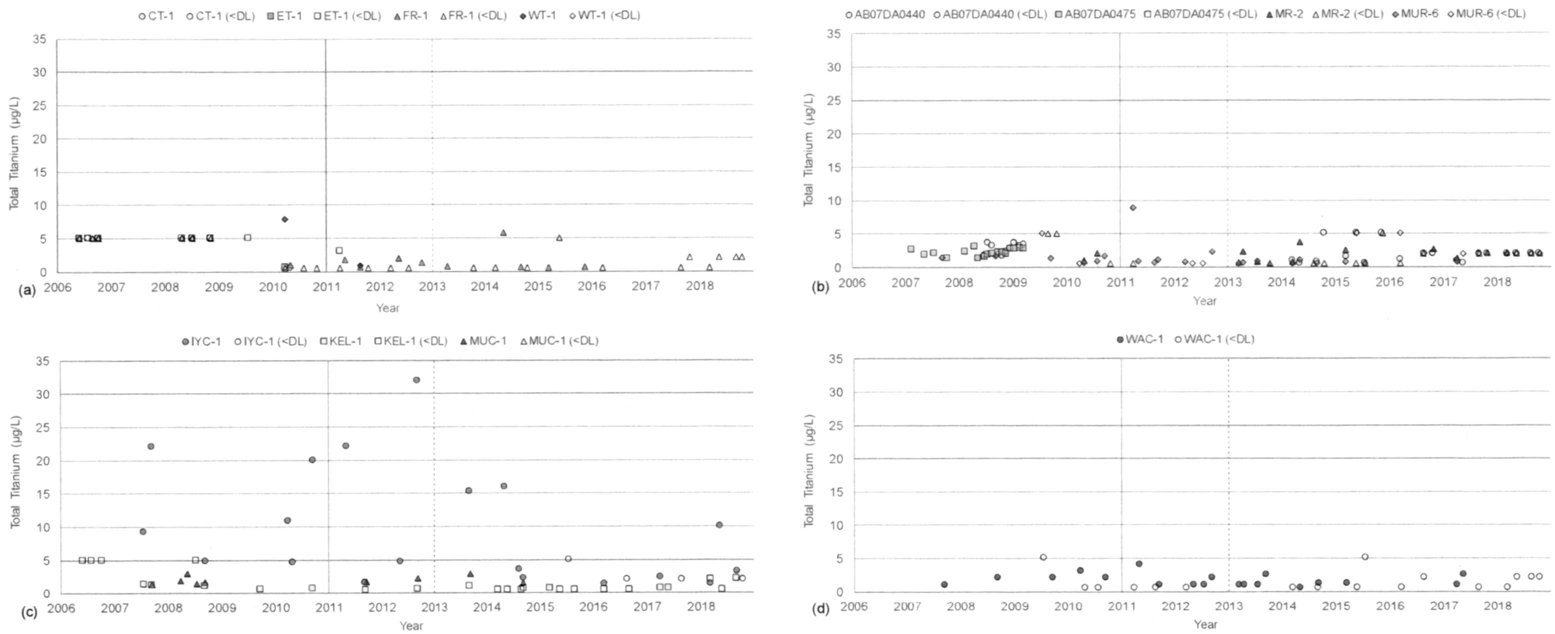
Figure 4-7: **Time Series Plots of Total Antimony**



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

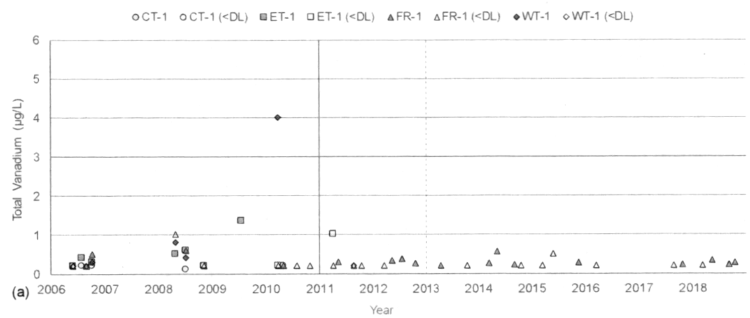
Figure 4-8: Time Series Plots of Methyl Mercury

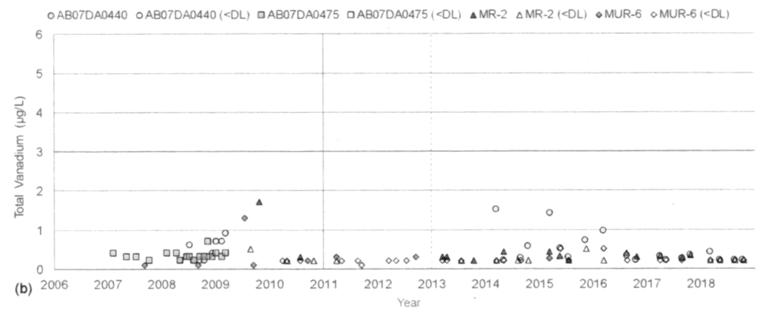


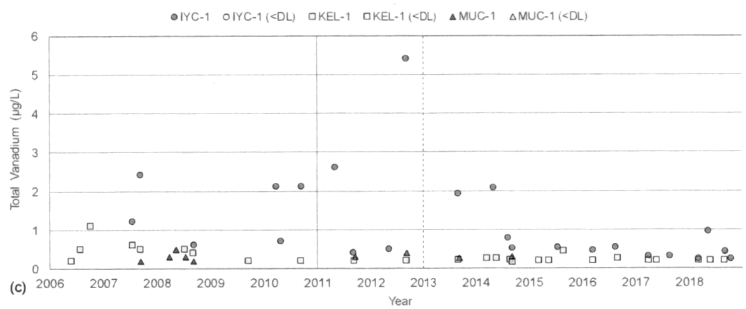
Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

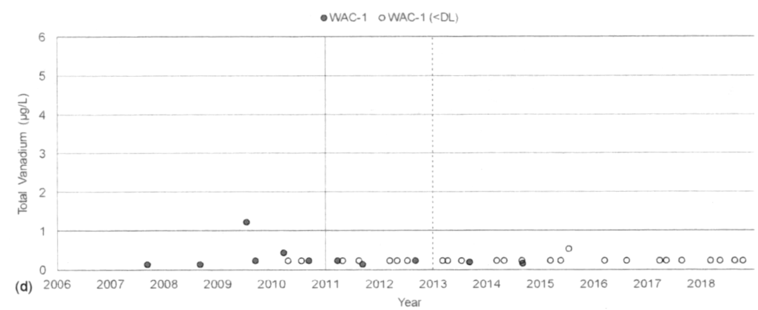
DL = detection limit; < = less than.

Figure 4-9: Time Series Plots of Total Titanium





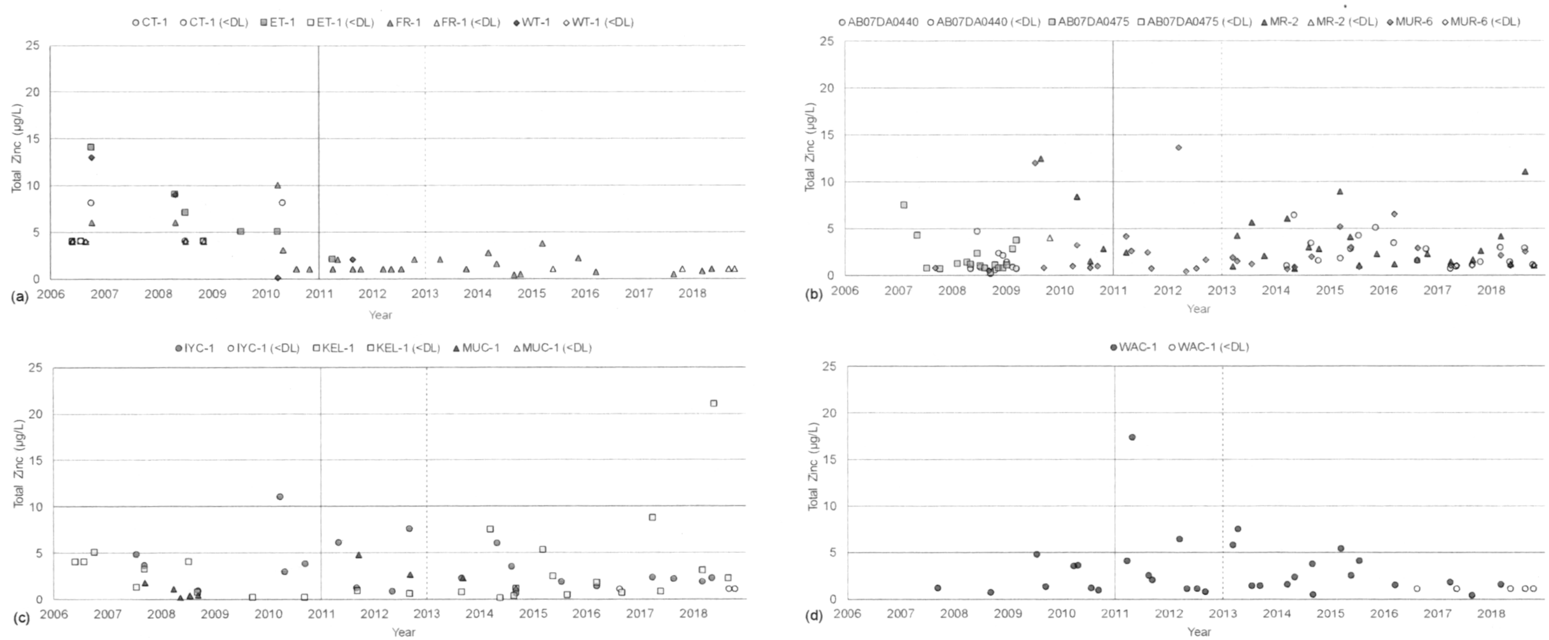




Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

Figure 4-10: **Time Series Plots of Total Vanadium**



Panel (a) shows Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) shows Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) shows Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) shows Wapasu Creek watershed stations (Station WAC-1).

DL = detection limit; < = less than.

Figure 4-11: Time Series Plots of Total Zinc

4.8 Summary of Muskeg Lake Water and Sediment Quality

4.8.1 Guideline Comparisons

4.8.1.1 Water Quality

Water in Muskeg Lake was slightly alkaline and well-oxygenated in all sampling years, with the exception of dissolved oxygen in winter 2018, which was below the chronic WQG (Table 4-12). Although the winter 2018 dissolved oxygen level was below the chronic WQG (GOA 2018), it was above the acute WQG and remained highly suitable for the fish species present in Muskeg Lake (optimal dissolved oxygen concentrations of 2.0 to 6.0 mg/L – Golder 2008). Concentrations of TDS ranged from 150 to 320 mg/L and were well below the wildlife guideline of 3,000 mg/L. Total and dissolved organic carbon concentrations were found at moderate to high concentrations, ranging from 16 to 22 mg/L and 17 to 22 mg/L, respectively. Colour has declined over time. Concentrations of conventional parameters, major ions and nutrients were all below guidelines. Most concentrations of total phenolics (and/or phenol) were above the wildlife guideline and sometimes above the chronic WQG. All metal concentrations were below guidelines. Concentrations of PAHs and PANHs were generally below the DLs (with the exception of most naphthalene results) and were below guidelines in all samples.

Table 4-12: Muskeg Lake Water Quality Data Compared to Guidelines, 2012 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of: Aquatic Life		GOA (2018) Guidelines for the Protection of:	Health Canada (2017)		Station NNL-1															
		Acute	Chronic	Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO	27-May-12	03-Sep-13	19-Mar-14	25-May-14	31-Aug-14	14-Mar-15	24-May-15	30-Aug-15	20-Mar-16	04-Sep-16	04-Apr-17	29-May-17	05-Sep-17	06-Mar-18	28-May-18	02-Sep-18
Field Measured																						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	8.2	-	7.8	7.8	8.1	7.9	8.4	8.2	7.4	7.9	8.6	7.5	7.8	7.9	8.4	8.1
Specific conductivity	µS/cm	-	-	-	-	-	440	-	360	257	229	323	272	270	319	254	179	261	276	231	274	253
Temperature	°C	-	-	-	-	15	**16**[(S)]	-	1.0	14	**17**[(S)]	0.60	**19**[(S)]	**19**[(S)]	0.59	**15**[(S)]	-1.8	**16**[(S)]	15	0.40	**16**[(S)]	11
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	11	-	11	10	8.0	8.2	8.6	8.1	9.7	8.2	7.5	10	7.3	**6.0**[(C)]	8.2	10
Conventional Parameters																						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	8.3	8.3	8.0	8.1	7.9	8.1	8.3	8.3	8.1	8.3	8.2	8.3	8.3	8.2	8.2	8.3
Specific conductivity	µS/cm	-	-	-	-	-	480	310	350	290	270	320	260	270	320	260	300	270	270	350	270	270
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	250	137	174	144	137	150	135	147	147	124	140	140	130	170	140	120
Total alkalinity, as $CaCO_3$	mg/L	-	20[(a)]	-	-	-	150	110	130	110	110	130	110	120	140	130	130	120	140	160	140	130
Total dissolved solids	mg/L	-	-	3,000	-	500	320	200	250	200	200	210	170	170	200	180	200	190	190	210	200	200
Total suspended solids	mg/L	-	-	-	-	-	3.0	<1.0	<1.0	1.3	<1.0	<1.0	1.4	<1.0	<1.0	2.7	<1.0	<1.0	7.3	4.7	2.5	<1.0
Total organic carbon	mg/L	-	-	-	-	-	16	21	22	18	19	22	16	18	20	18	18	17	19	21	18	19
Dissolved organic carbon	mg/L	-	-	-	-	-	15	20	22	18	19	22	17	17	20	18	18	17	19	20	18	19
Colour	TCU	-	-	-	-	15	8.0	**20**[(S)]	**27**[(S)]	**19**[(S)]	**20**[(S)]	**22**[(S)]	**18**[(S)]	14	**16**[(S)]	13	13	12	11	15	11	13
Major Ions																						
Bicarbonate, as $CaCO_3$	mg/L	-	-	-	-	-	190	140	160	130	130	160	130	150	170	150	160	150	170	190	170	150
Calcium	mg/L	-	-	1,000	-	-	58	37	40	33	37	41	38	41	41	35	40	39	35	47	37	35
Carbonate, as $CaCO_3$	mg/L	-	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<1.0	<1.0
Chloride	mg/L	640	120	-	-	250	1.0	2.0	1.7	<1.0	1.4	1.5	1.3	<1.0	1.7	1.3	1.6	1.7	1.4	2.3	1.8	2.1
Magnesium	mg/L	-	-	-	-	-	21	12	13	11	11	11	10.0	11	11	9.3	11	10	9.8	13	9.5	9.0
Potassium	mg/L	-	-	-	-	-	2.7	1.6	2.5	1.3	1.3	1.6	1.4	1.6	1.7	1.4	1.7	1.7	1.5	1.9	1.4	1.4
Sodium	mg/L	-	-	-	-	200	6.0	9.0	9.3	8.1	8.6	9.9	9.0	10	9.9	9.2	10	9.9	10	13	10	10
Sulphate	mg/L	-	309 to 429[(b, c)]	1,000	-	500	100	39	46	35	29	32	24	20	25	16	17	15	12	18	12	9.8
Sulphide	mg/L	-	0.0043 to 0.043[(d)]	-	-	0.050	0.0034	<0.002	<0.002	<0.002	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.0028	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.0023
Nutrients and Biological Indicators																						
Nitrate + nitrite	mg-N/L	-	-	100	-	-	<0.003	0.0070	0.12	<0.01	<0.01	0.025	0.026	<0.02	0.045	<0.02	0.12	<0.01	0.017	0.20	<0.014	<0.014
Total ammonia	mg-N/L	-	0.20[(e)]	-	-	-	<0.05	<0.05	0.62	<0.05	0.053	0.080	<0.05	0.11	0.24	<0.05	<0.05	0.016	0.025	0.045	0.032	0.024
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	0.48	0.73	0.80	0.62	0.85	0.78	0.77	0.66	0.83	0.64	0.81	0.68	1.1	1.0	1.1	0.81
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	0.48	0.74	0.92	0.62	0.85	0.81	0.80	0.66	0.88	0.64	0.93	0.68	1.1	1.2	1.1	0.81
Total phosphorus	mg-P/L	-	-	-	-	-	0.010	0.010	0.054	0.0070	0.0070	0.022	0.0066	0.0057	0.0080	0.0076	0.0087	0.0084	0.018	0.019	0.031	0.024
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.0040	0.0038	0.017	0.031	0.0030	0.0030	0.0026	0.0042	0.0088	0.0068	<0.001	0.0030	0.0040	0.0044	0.025	0.0032
Biochemical oxygen demand	mg/L	-	-	-	-	-	<2.0	<2.0	3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.3	<2.0	2.1	<2.0	<2.0	<2.0
General Organics																						
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(f)]	mg/L	-	0.0040	0.0020	-	-	-	-	-	-	-	-	-	-	-	-	<0.002	<0.002	**0.0046**[(C, W)]	**0.0045**[(C, W)]	**0.0038**[(W)]	**0.0075**[(C, W)]
Total phenolics[(g)]	mg/L	-	0.0040	0.0020	-	-	**0.0026**[(W)]	**0.0062**[(C, W)]	**0.0069**[(C, W)]	**0.0032**[(W)]	**0.0040**[(W)]	<0.002	**0.0039**[(W)]	<0.002	**0.0035**[(W)]	<0.002	-	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals																						
Aluminum	µg/L	-	-	5,000	-	-	2.4	12	35	1.3	12	15	10	14	7.7	25	64	18	61	67	26	30
Antimony	µg/L	-	-	-	6.0	-	0.057	0.047	0.076	0.029	0.029	0.080	0.025	0.024	0.033	0.025	0.020	<0.02	0.037	0.047	0.045	0.027
Arsenic	µg/L	-	5.0	25	10	-	0.32	0.40	0.47	0.37	0.39	0.41	0.39	0.45	0.43	0.40	0.43	0.37	0.50	0.53	0.37	0.43
Barium	µg/L	-	-	-	1,000	-	74	38	45	38	37	47	34	38	49	38	48	38	44	61	40	40
Beryllium	µg/L	-	-	100	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	29,000	1,500	5,000	5,000	-	<50	<50	<50	<50	32	45	32	34	45	40	44	37	43	55	39	39
Cadmium	µg/L	2.5 to 5.3[(b)]	0.18 to 0.34[(b)]	80	5.0	-	0.0058	<0.005	0.010	0.0070	<0.005	0.0094	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	-	1.0[(h)]	50	50[(h)]	-	<0.1	<0.1	0.11	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	0.15	0.21	<0.1
Cobalt	µg/L	-	1.1 to 1.5[(b)]	1,000	-	-	0.026	0.037	0.075	0.044	0.044	0.038	0.038	0.046	0.032	0.060	0.050	0.050	0.085	0.099	0.039	0.058
Copper	µg/L	19 to 39[(b)]	7.0[(b)]	500	-	1,000	0.68	0.41	1.2	0.33	0.47	0.46	0.34	0.30	0.37	0.32	0.44	0.36	0.43	0.57	0.40	0.34
Iron	µg/L	-	-	-	-	300	2.8	19	48	52	25	23	29	31	19	74	39	27	120	100	35	69

Table 4-12: Muskeg Lake Water Quality Data Compared to Guidelines, 2012 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of:			Health Canada (2017)		Station NNL-1															
		Aquatic Life		Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO	27-May-12	03-Sep-13	19-Mar-14	25-May-14	31-Aug-14	14-Mar-15	24-May-15	30-Aug-15	20-Mar-16	04-Sep-16	04-Apr-17	29-May-17	05-Sep-17	06-Mar-18	28-May-18	02-Sep-18
		Acute	Chronic																			
Lead	µg/L	-	4.0 to 7.0[b]	100	10	-	<0.005	0.62	0.074	0.037	0.022	0.032	0.080	0.019	0.012	0.028	0.025	0.069	0.12	0.096	0.030	0.043
Lithium	µg/L	-	-	-	-	-	11	8.1	8.4	7.9	6.9	9.0	6.8	6.6	8.4	7.3	8.0	7.0	8.0	9.6	7.1	7.5
Manganese	µg/L	-	-	-	-	50	0.16	5.2	3.9	7.2	6.9	1.6	6.8	16	2.7	26	7.2	9.0	25	7.8	7.0	23
Mercury	µg/L	0.013	0.0050	3.0	1.0	-	0.00080	0.00089	0.0012	0.00075	0.00086	0.00097	0.00090	0.00081	0.00046	0.00045	0.00048	0.00059	0.00095	0.00076	0.00067	0.00065
Methyl mercury	µg/L	0.0020	0.0010	-	-	-	<0.00008	<0.00008	0.00010	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Molybdenum	µg/L	-	73	500	-	-	1.3	0.54	0.70	0.47	0.38	0.48	0.34	0.33	0.41	0.31	0.35	0.26	0.31	0.39	0.25	0.26
Nickel	µg/L	547 to 1,019[b]	61 to 113[b]	1,000	-	-	1.7	0.89	1.2	1.0	0.73	0.98	0.70	0.76	0.78	0.64	1.3	0.77	0.70	1.2	0.76	0.64
Selenium	µg/L	-	2.0	50	50	-	0.12	0.064	0.074	0.052	<0.04	0.055	<0.04	<0.04	0.063	0.054	0.042	<0.04	<0.04	0.048	<0.04	<0.04
Silver	µg/L	-	0.25	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01
Strontium	µg/L	-	-	-	-	-	110	78	87	76	75	95	68	77	77	76	88	78	82	99	78	79
Thallium	µg/L	-	0.80	-	-	-	0.0071	0.0020	0.0070	0.0040	0.0020	0.0031	0.0030	0.0040	0.0030	0.0040	0.0043	0.0041	0.0040	0.0056	0.0037	0.0036
Titanium	µg/L	-	-	-	-	-	<0.5	<0.5	0.70	0.74	<0.5	0.76	<0.5	<0.5	<0.5	0.81	1.2	0.81	1.7	2.6	<2.0	<2.0
Uranium	µg/L	33	15	200	20	-	2.8	0.86	0.99	0.78	0.55	0.73	0.46	0.46	0.56	0.35	0.43	0.35	0.36	0.48	0.31	0.27
Vanadium	µg/L	-	-	100	-	-	<0.2	0.27	0.33	0.20	0.25	<0.2	<0.2	0.27	<0.2	0.28	0.21	<0.2	0.35	0.37	0.22	<0.2
Zinc	µg/L	-	30	50,000	-	5,000	0.48	1.9	6.7	<0.1	1.1	4.4	1.7	0.32	1.2	0.52	4.0	0.93	2.0	2.7	1.9	1.3
Dissolved Metals																						
Aluminum	µg/L	100[d]	50[d]	-	-	-	7.3	5.7	4.3	1.3	2.0	1.3	1.8	14	1.8	2.0	1.8	1.9	3.9	1.1	4.3	3.0
Antimony	µg/L	-	-	-	-	-	0.048	0.055	0.064	0.028	0.024	0.039	0.030	0.035	0.033	0.030	0.028	0.024	0.032	0.040	0.050	0.032
Arsenic	µg/L	-	-	-	-	-	0.27	0.42	0.47	0.34	0.39	0.41	0.40	0.54	0.46	0.39	0.41	0.36	0.47	0.54	0.34	0.40
Barium	µg/L	-	-	-	-	-	73	38	43	36	36	44	38	43	49	39	50	43	44	59	40	38
Beryllium	µg/L	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	-	-	-	-	-	<50	<50	<50	<50	34	43	36	47	42	42	45	37	38	58	40	40
Cadmium	µg/L	-	-	-	-	-	<0.005	<0.005	0.0070	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<0.1
Cobalt	µg/L	-	-	-	-	-	0.015	0.034	0.047	0.020	0.023	0.026	0.017	0.030	0.027	0.028	0.029	0.026	0.034	0.044	0.017	0.028
Copper	µg/L	-	-	-	-	-	0.65	0.40	0.87	0.46	0.28	0.36	0.32	0.33	0.39	0.27	0.37	0.31	0.36	0.47	0.31	0.26
Iron	µg/L	-	300	-	-	-	2.0	15	12	9.2	5.0	8.8	6.0	8.0	5.9	5.3	4.4	3.4	5.8	4.3	2.1	9.4
Lead	µg/L	-	-	-	-	-	0.0071	0.50	0.016	<0.005	<0.005	0.010	0.017	0.0070	<0.005	<0.005	<0.005	0.011	0.0060	0.0075	<0.005	0.0098
Lithium	µg/L	-	-	-	-	-	11	8.4	9.3	7.4	8.1	8.7	7.6	8.1	8.1	7.5	8.2	7.4	7.5	10	7.2	8.1
Manganese	µg/L	-	-	-	-	-	0.062	4.9	0.28	0.12	0.11	0.47	0.12	0.16	0.34	0.12	0.11	0.19	0.14	1.2	0.056	0.072
Mercury	µg/L	-	-	-	-	-	-	-	0.0013	0.00041	0.00070	0.00035	0.00041	0.00059	0.00046	0.00017	0.00022	0.00018	0.00023	<0.00011	0.00034	0.00026
Molybdenum	µg/L	-	-	-	-	-	1.2	0.51	0.75	0.46	0.41	0.46	0.31	0.41	0.40	0.30	0.37	0.27	0.31	0.41	0.27	0.23
Nickel	µg/L	-	-	-	-	-	1.6	0.89	1.2	1.1	0.70	0.90	0.73	0.87	0.93	0.58	0.94	0.80	0.63	1.1	0.68	0.56
Selenium	µg/L	-	-	-	-	-	0.069	0.067	0.069	0.054	0.049	0.056	<0.04	0.051	0.043	<0.04	0.046	0.045	0.045	0.059	<0.04	<0.04
Silver	µg/L	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	µg/L	-	-	-	-	-	110	80	86	70	73	86	75	84	89	77	91	82	86	110	82	78
Thallium	µg/L	-	-	-	-	-	0.0080	0.0020	0.0060	0.0040	0.0030	0.0040	0.0030	0.0040	0.0030	0.0040	0.0044	0.0040	0.0040	0.0044	0.0021	0.0023
Titanium	µg/L	-	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	µg/L	-	-	-	-	-	2.9	0.81	1.0	0.80	0.60	0.61	0.46	0.50	0.57	0.34	0.45	0.38	0.35	0.48	0.33	0.24
Vanadium	µg/L	-	-	-	-	-	<0.2	<0.2	0.20	<0.2	0.25	0.22	<0.2	0.30	<0.2	0.22	<0.2	<0.2	0.25	0.25	<0.2	<0.2
Zinc	µg/L	-	-	-	-	-	0.17	0.85	4.8	0.13	0.14	3.9	2.7	0.14	0.72	0.21	1.7	0.65	0.84	1.9	0.92	0.66
Target PAHs and Alkylated PAHs																						
Acenaphthene	µg/L	-	5.8	-	-	-	<0.1	<0.1	<0.005	<0.005	<0.005	<0.005	0.018	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted acenaphthene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	µg/L	-	-	-	-	-	<0.1	<0.1	<0.005	<0.005	<0.005	<0.005	0.0075	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Anthracene	µg/L	-	0.012	-	-	-	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dibenzo(a,h)anthracene	µg/L	-	-	-	-	-	<0.0075	<0.0075	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)anthracene	µg/L	-	0.018	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(c)phenanthrene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table 4-12: Muskeg Lake Water Quality Data Compared to Guidelines, 2012 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of: Aquatic Life		Wildlife Health (Livestock)	Health Canada (2017)		Station NNL-1															
		Acute	Chronic		Drinking Water MAC	Drinking Water AO	27-May-12	03-Sep-13	19-Mar-14	25-May-14	31-Aug-14	14-Mar-15	24-May-15	30-Aug-15	20-Mar-16	04-Sep-16	04-Apr-17	29-May-17	05-Sep-17	06-Mar-18	28-May-18	02-Sep-18
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Biphenyl	µg/L	-	-	-	-	-	<0.02	<0.02	0.0054	<0.005	<0.005	<0.005	0.020	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted biphenyl	µg/L	-	-	-	-	-	<0.02	<0.02	0.0079	<0.005	0.0071	<0.005	0.0084	<0.005	<0.005	<0.005	<0.005	0.0081	<0.005	<0.005	<0.005	<0.005
C2 substituted biphenyl	µg/L	-	-	-	-	-	<0.02	<0.02	0.0090	<0.005	<0.005	<0.005	<0.005	0.0055	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chrysene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	-	-	-	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	-	-	<0.0085	10	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C4 substituted benzo(a)anthracene/chrysene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dibenzothiophene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted dibenzothiophene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted dibenzothiophene	µg/L	-	-	-	-	-	<0.02	0.10	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0058	<0.005	<0.005	<0.005	<0.005
C3 substituted dibenzothiophene	µg/L	-	-	-	-	-	<0.02	0.054	<0.005	<0.005	<0.005	0.0069	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C4 substituted dibenzothiophene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	0.0068	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	µg/L	-	0.040	-	-	-	<0.04	<0.04	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(b&j)fluoranthene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(k)fluoranthene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(1,2,3-cd)fluoranthene	µg/L	-	-	-	-	-	-	-	-	<0.029	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluorene	µg/L	-	3.0	-	-	-	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	0.030	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted fluorene	µg/L	-	-	-	-	-	<0.05	<0.05	0.0061	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted fluorene	µg/L	-	-	-	-	-	<0.05	<0.05	0.0077	<0.005	<0.005	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted fluorene	µg/L	-	-	-	-	-	<0.1	<0.05	<0.005	<0.005	<0.005	0.026	0.032	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Naphthalene	µg/L	-	1.0	-	-	-	<0.1	<0.1	0.50	0.021	0.015	0.035	0.59	0.057	0.0087	0.011	0.024	0.020	0.015	0.011	0.022	0.014
1-Methylnaphthalene	µg/L	-	-	-	-	-	-	-	0.18	0.0058	<0.005	0.0050	0.046	0.012	<0.005	<0.005	0.0062	0.0091	<0.005	<0.005	0.0074	<0.005
2-Methylnaphthalene	µg/L	-	-	-	-	-	-	-	0.34	0.011	0.0073	0.0088	0.096	0.023	<0.005	0.0064	0.014	0.018	0.0056	0.0057	0.013	0.0067
C1 substituted naphthalene	µg/L	-	-	-	-	-	<0.1	<0.1	0.60	0.018	0.012	0.015	0.15	0.038	<0.005	0.012	0.021	0.025	0.0091	0.0089	0.021	0.011
C2 substituted naphthalene	µg/L	-	-	-	-	-	<0.1	<0.1	0.12	<0.005	0.0082	0.0079	0.040	0.015	<0.005	0.0074	0.0055	0.0079	0.0073	0.0071	0.0068	0.0054
C3 substituted naphthalene	µg/L	-	-	-	-	-	<0.1	<0.1	0.014	0.0071	0.0068	0.0083	0.011	0.011	0.0055	0.0082	0.0068	0.014	0.0069	0.010	0.0066	<0.005
C4 substituted naphthalene	µg/L	-	-	-	-	-	<0.1	<0.1	0.018	0.0081	<0.005	0.0072	0.0064	0.0057	<0.005	<0.005	<0.005	0.0064	0.0062	0.0074	<0.005	<0.005
Perylene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(g,h,i)perylene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenanthrene	µg/L	-	0.40	-	-	-	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	0.0098	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted phenanthrene/anthracene	µg/L	-	-	-	-	-	<0.05	<0.05	0.0051	<0.005	<0.005	0.0052	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted phenanthrene/anthracene	µg/L	-	-	-	-	-	<0.05	<0.05	0.0062	<0.005	<0.005	0.0096	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted phenanthrene/anthracene	µg/L	-	-	-	-	-	<0.05	<0.05	0.0052	0.0063	<0.005	0.0070	<0.005	<0.005	<0.005	<0.005	<0.005	0.0063	0.0072	0.0055	<0.005	<0.005
C4 substituted phenanthrene/anthracene	µg/L	-	-	-	-	-	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pyrene	µg/L	-	0.025	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted fluoranthene/pyrene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted fluoranthene/pyrene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted fluoranthene/pyrene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C4 substituted fluoranthene/pyrene	µg/L	-	-	-	-	-	<0.02	<0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(c,d-123)pyrene	µg/L	-	-	-	-	-	<0.0085	<0.0085	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(a)pyrene	µg/L	-	0.015	-	0.040	-	<0.0075	<0.0075	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Benzo(e)pyrene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Retene	µg/L	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table 4-12: Muskeg Lake Water Quality Data Compared to Guidelines, 2012 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of:			Health Canada (2017)		Station NNL-1															
		Aquatic Life		Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO	27-May-12	03-Sep-13	19-Mar-14	25-May-14	31-Aug-14	14-Mar-15	24-May-15	30-Aug-15	20-Mar-16	04-Sep-16	04-Apr-17	29-May-17	05-Sep-17	06-Mar-18	28-May-18	02-Sep-18
		Acute	Chronic																			
PANHs																						
Acridine	µg/L	-	4.4	-	-	-	<0.2	<0.2	<0.025	<0.005	<0.005	<0.005	0.070	<0.035	<0.005	<0.005	<0.005	0.013	0.014	0.012	0.0060	0.023
Quinoline	µg/L	-	3.4	-	-	-	<0.2	<0.2	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

[a] Guideline is a minimum value, unless the background concentration or value is lower.
[b] Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (120 to 250 mg/L). The guideline is calculated based on the individual hardness value for each sample.
[c] For one sample, water hardness was 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
[d] Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (7.4 to 8.6). The guideline is calculated based on the individual pH for each sample.
[e] The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.20 mg-N/L) is presented and was calculated based on the combination of field pH (8.4) and water temperature (18.5°C). The guideline is calculated based on the individual field pH and temperature measurements for each sample.
[f] Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
[g] Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
[h] Guideline is for chromium VI.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline or below the DO guideline.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline.
Note: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; DO = dissolved oxygen.

4.8.1.2 Sediment Quality

Concentrations of most sediment quality parameters in Muskeg Lake were below guidelines (Table 4-13). Sand was the dominant fraction of inorganic bottom sediments and TOC content was low, which is unusual for natural lake sediments in the region but not unexpected for this newly constructed lake. It is expected that over time the fine sediment fraction and TOC of Muskeg Lake sediments will increase to values typical of other lakes in the region. Concentrations of metals were generally low; however, concentrations of aluminum (1,500 to 4,400 mg/kg) calcium (24,000 to 39,000 mg/kg), iron (6,000 to 8,800 mg/kg), and magnesium (6,000 to 11,000 mg/kg) were high. However, there are no sediment quality guidelines for these metals (CCME 1998) and high concentrations were also recorded in for these metals in Kearl Lake.

Organic, PAH and PANH parameters were below the sediment quality guidelines (CCME 1998) with five exceptions – concentrations of acenaphthylene (in 2016), acenaphthene (in 2016), pyrene (in 2013, 2015, 2016, and 2018), benzo(a)pyrene (in 2013 and 2016) and dibenzo(a,h)anthracene (in 2013, 2016, 2017, and 2018) were occasionally above the ISQGs (Table 4-13). All concentrations were below the PELs. The concentrations of hydrocarbons and PAHs suggest that the sediment sample collected in the Muskeg Lake contained eroded oil sands.

Table 4-13: Muskeg Lake Sediment Quality Data Compared to Guidelines, 2013 to 2018

Parameter	Unit [dry wt.]	CCME (1998) Guidelines		Station NNL-1					
		ISQG	PEL	03-Sep-13	31-Aug-14	30-Aug-15	04-Sep-16	05-Sep-17	02-Sep-18
Particle Size and Moisture Content									
Sand content	%	-	-	74	54	74	63	73	62
Silt content	%	-	-	19	27	16	30	20	27
Clay content	%	-	-	7.4	19	11	6.9	7.2	11
Moisture content	%	-	-	18	27	19	32	25	26
Carbon Content									
Total inorganic carbon	%	-	-	0.65	0.81	1.2	1.5	0.6	0.89
Total organic carbon	%	-	-	2.1	0.91	0.82	2.0	1.4	2.4
Total carbon	%	-	-	2.7	1.7	2.0	3.5	2.0	3.3
Organics									
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	-	-	<12	<12	<12	<12	<10	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	-	-	390	39	190	480	180	300
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	-	-	3,800	740	2,100	4,000	1,700	2,600
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	-	-	1,900	440	1,200	2,000	900	1,200
Total petroleum hydrocarbons	mg/kg	-	-	2,700	370	3,800	7,300	2,700	7,000
Total Metals									
Aluminum	mg/kg	-	-	1,500	4,400	2,100	3,400	1,500	3,000
Antimony	mg/kg	-	-	<1.0	<1.0	<0.5	<0.5	<0.5	<0.5
Arsenic	mg/kg	5.9	17	1.1	1.2	1.1	1.3	1.0	1.4
Barium	mg/kg	-	-	17	50	16	28	18	29
Beryllium	mg/kg	-	-	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Boron	mg/kg	-	-	4.0	2.3	2.6	7.9	<2.0	4.5
Cadmium	mg/kg	0.6	3.5	<0.1	<0.1	<0.05	<0.05	<0.05	<0.05
Calcium	mg/kg	-	-	38,000	25,000	38,000	34,000	24,000	39,000
Chromium	mg/kg	37	90	10	7.4	6.2	7.8	5.9	8.3
Cobalt	mg/kg	-	-	1.9	2.1	1.7	2.3	1.8	2.7
Copper	mg/kg	36	197	<5.0	12	<1.0	4.0	2.8	4.4
Iron	mg/kg	-	-	6,000	7,500	6,400	7,000	8,800	7,000
Lead	mg/kg	35	91	2.4	3.1	2.2	2.9	2.0	3.3
Lithium	mg/kg	-	-	<10	<10	<10	<10	<10	<10
Magnesium	mg/kg	-	-	8,400	6,000	9,400	9,700	6,600	11,000
Manganese	mg/kg	-	-	90	94	110	120	90	140

Table 4-13: Muskeg Lake Sediment Quality Data Compared to Guidelines, 2013 to 2018

Parameter	Unit [dry wt.]	CCME (1998) Guidelines		Station NNL-1					
		ISQG	PEL	03-Sep-13	31-Aug-14	30-Aug-15	04-Sep-16	05-Sep-17	02-Sep-18
Mercury	mg/kg	0.17	0.49	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	mg/kg	-	-	0.58	<0.4	<0.4	0.62	<0.4	0.64
Nickel	mg/kg	-	-	9.2	6.6	6.4	7.3	5.2	8.7
Potassium	mg/kg	-	-	390	780	360	680	340	600
Selenium	mg/kg	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	mg/kg	-	-	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2
Sodium	mg/kg	-	-	< 50	65	< 50	80	< 50	56
Strontium	mg/kg	-	-	23	31	21	25	24	27
Thallium	mg/kg	-	-	<0.3	<0.3	<0.1	<0.1	<0.1	<0.1
Titanium	mg/kg	-	-	33	72	30	51	48	56
Uranium	mg/kg	-	-	<1.0	<1.0	0.25	0.47	0.75	0.49
Vanadium	mg/kg	-	-	7.5	10	6.5	11	6.3	11
Zinc	mg/kg	123	315	<10	10	<10	11	<10	11
Target PAHs and Alkylated PAHs									
Acenaphthene	mg/kg	0.0067	0.089	0.0054	<0.0005	0.0042	**0.03**(I)	0.0052	<0.005
C1 substituted acenaphthene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	mg/kg	0.0059	0.13	<0.005	<0.0005	<0.0005	**0.012**(I)	<0.0025	<0.005
Anthracene	mg/kg	0.047	0.25	<0.004	<0.0005	<0.0005	<0.005	<0.0025	<0.005
Dibenzo(a,h)anthracene	mg/kg	0.0062	0.14	**0.019**(I)	<0.0021	0.0049	**0.019**(I)	**0.0078**(I)	**0.013**(I)
Benzo(a)anthracene	mg/kg	0.032	0.39	<0.005	<0.0018	0.0029	0.018	0.005	0.01
Benzo(c)phenanthrene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.05	<0.025	<0.05
C1 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	0.42	0.11	0.27	0.6	0.22	0.38
C2 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	0.45	0.086	0.24	0.44	0.16	0.46
Biphenyl	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted biphenyl	mg/kg	-	-	<0.005	<0.005	0.012	0.03	<0.005	<0.005
C2 substituted biphenyl	mg/kg	-	-	<0.005	<0.005	0.016	0.015	0.01	0.025
Chrysene	mg/kg	0.057	0.86	<0.005	<0.0032	0.0036	<0.005	<0.0025	0.0079
C1 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	0.36	0.068	0.3	0.62	0.17	0.38
C2 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	4.3	0.36	1.2	2.4	0.79	1.9
C3 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	1.5	0.26	0.87	1.5	0.46	1.1
C4 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	0.5	0.12	0.061	0.19	0.12	0.32
Dibenzothiophene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table 4-13: Muskeg Lake Sediment Quality Data Compared to Guidelines, 2013 to 2018

Parameter	Unit [dry wt.]	CCME (1998) Guidelines		Station NNL-1					
		ISQG	PEL	03-Sep-13	31-Aug-14	30-Aug-15	04-Sep-16	05-Sep-17	02-Sep-18
C1 substituted dibenzothiophene	mg/kg	-	-	<0.005	<0.005	0.035	<0.005	<0.005	0.014
C2 substituted dibenzothiophene	mg/kg	-	-	0.24	0.027	0.19	0.28	0.11	0.6
C3 substituted dibenzothiophene	mg/kg	-	-	0.56	0.029	0.23	0.55	0.16	0.99
C4 substituted dibenzothiophene	mg/kg	-	-	1.4	0.079	0.45	0.87	0.42	1.8
Fluoranthene	mg/kg	0.11	2.4	<0.005	<0.0011	0.0055	0.019	0.0042	0.0067
Benzo(b,j)fluoranthene	mg/kg	-	-	0.055	0.0084	0.033	0.08	0.027	0.045
Benzo(k)fluoranthene	mg/kg	-	-	<0.005	<0.0005	0.0082	0.012	0.0034	0.0074
Fluorene	mg/kg	0.021	0.14	<0.005	<0.0005	0.0017	<0.005	<0.0025	<0.005
C1 substituted fluorene	mg/kg	-	-	0.025	<0.005	0.011	0.015	0.009	0.016
C2 substituted fluorene	mg/kg	-	-	0.13	0.013	0.055	0.1	0.033	0.099
C3 substituted fluorene	mg/kg	-	-	0.25	<0.005	0.62	0.69	0.19	0.5
Naphthalene	mg/kg	0.035	0.39	<0.005	0.0016	0.0013	<0.005	<0.0025	<0.005
1-Methylnaphthalene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
2-Methylnaphthalene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.05	<0.025	<0.05
C1 substituted naphthalene	mg/kg	-	-	0.01	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted naphthalene	mg/kg	-	-	0.031	0.019	0.023	0.052	0.048	0.051
C3 substituted naphthalene	mg/kg	-	-	0.071	0.0082	0.048	0.083	0.022	0.053
C4 substituted naphthalene	mg/kg	-	-	0.19	<0.005	0.11	0.12	0.043	0.17
Perylene	mg/kg	-	-	0.087	0.022	0.056	0.14	0.059	0.064
Benzo(g,h,i)perylene	mg/kg	-	-	0.037	<0.011	0.014	0.044	0.016	0.026
Phenanthrene	mg/kg	0.042	0.52	<0.005	<0.0013	0.0079	<0.005	<0.0025	<0.005
C1 substituted phenanthrene / anthracene	mg/kg	-	-	0.049	0.0094	0.086	0.072	0.021	0.04
C2 substituted phenanthrene / anthracene	mg/kg	-	-	0.26	0.042	0.2	0.26	0.1	0.22
C3 substituted phenanthrene / anthracene	mg/kg	-	-	0.65	0.073	0.49	0.77	0.36	1.2
C4 substituted phenanthrene / anthracene	mg/kg	-	-	1.2	0.11	0.97	1.4	0.65	1.5
Pyrene	mg/kg	0.053	0.88	**0.1**(I)	0.02	**0.067**(I)	**0.15**(I)	0.052	**0.077**(I)
C1 substituted fluoranthene / pyrene	mg/kg	-	-	0.49	0.086	0.37	0.57	0.21	0.57
C2 substituted fluoranthene / pyrene	mg/kg	-	-	1.3	0.26	0.99	1.5	0.65	1.7
C3 substituted fluoranthene / pyrene	mg/kg	-	-	3.4	0.78	3.0	4.7	2.3	4.9
C4 substituted fluoranthene / pyrene	mg/kg	-	-	2.7	0.4	1.9	2.0	1.5	2.7
Indeno(c,d-123)pyrene	mg/kg	-	-	0.021	0.0057	0.01	0.043	0.011	0.016
Benzo(a)pyrene	mg/kg	0.032	0.78	**0.042**(I)	0.0037	0.018	**0.061**(I)	0.02	0.029

Table 4-13: Muskeg Lake Sediment Quality Data Compared to Guidelines, 2013 to 2018

Parameter	Unit [dry wt.]	CCME (1998) Guidelines		Station NNL-1					
		ISQG	PEL	03-Sep-13	31-Aug-14	30-Aug-15	04-Sep-16	05-Sep-17	02-Sep-18
Benzo(e)pyrene	mg/kg	-	-	0.089	0.021	0.038	0.12	0.038	0.06
Retene	mg/kg	-	-	0.044	<0.005	0.038	0.061	<0.005	0.017
PANHs									
Acridine	mg/kg	-	-	<0.01	<0.01	<0.01	<0.1	<0.05	<0.1
Quinoline	mg/kg	-	-	0.011	<0.01	<0.01	-	<0.05	<0.1

I = Value higher than the CCME (1998) Interim Sediment Quality Guideline.
Note: **Bolded** values are higher than sediment quality guidelines.
dry wt. = dry weight; CCME = Canadian Council of Ministers of the Environment; ISQG = interim sediment quality guidelines; PEL = probable effects level; < = less than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles; - = no guideline or data available.

4.8.2 Temporal Trends in Water Quality in Muskeg Lake

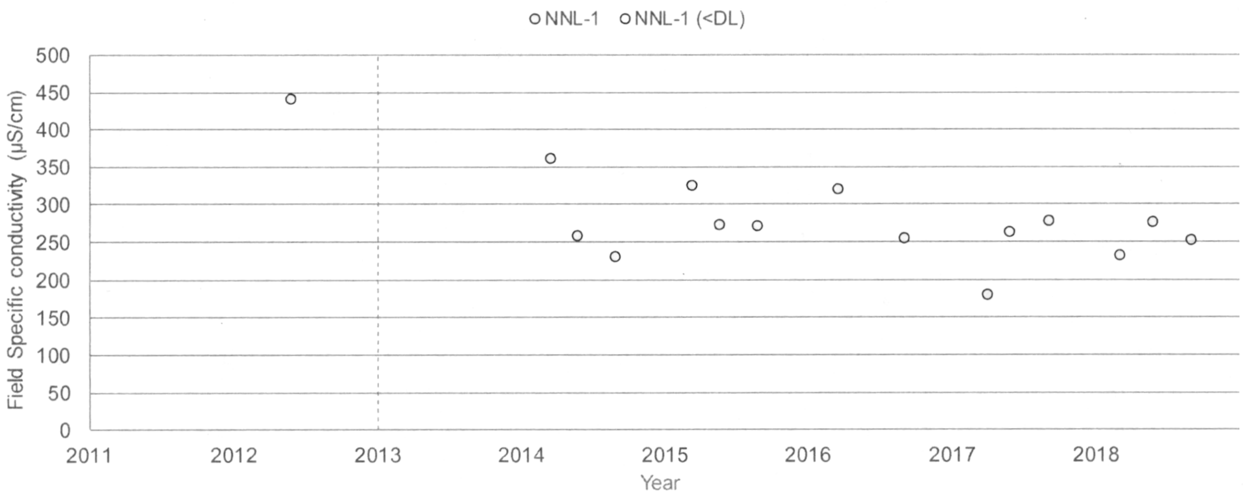
Time series plots for Station NNL-1 water quality parameters that exceeded water quality guidelines, and other parameters that showed temporal trends, are presented in Figures 4-12 to 4-26. Plots for the remaining parameters are provided in Appendix VII. On these plots, a dashed vertical line marks the beginning of the operational phase.

Field measured water quality parameters, conventional parameters, ions and nutrients either did not show temporal trends, or showed only weak trends (Appendix VII). Field measured specific conductivity showed a slight decreasing trend in Muskeg Lake over time, but this trend was weaker in the laboratory specific conductivity measurements (Figures 4-12 and 4-13). Temperature and dissolved oxygen concentrations showed no temporal trends, but both varied seasonally, with low values occurring during winter (Figures 4-14 and 4-15). Concentration of the major ions sodium and chloride showed increasing trends (Figures 4-16 and 4-17).

There was an increasing trend over time for total Kjeldahl nitrogen, and potentially for total phosphorus (Figures 4-18 and 4-19).

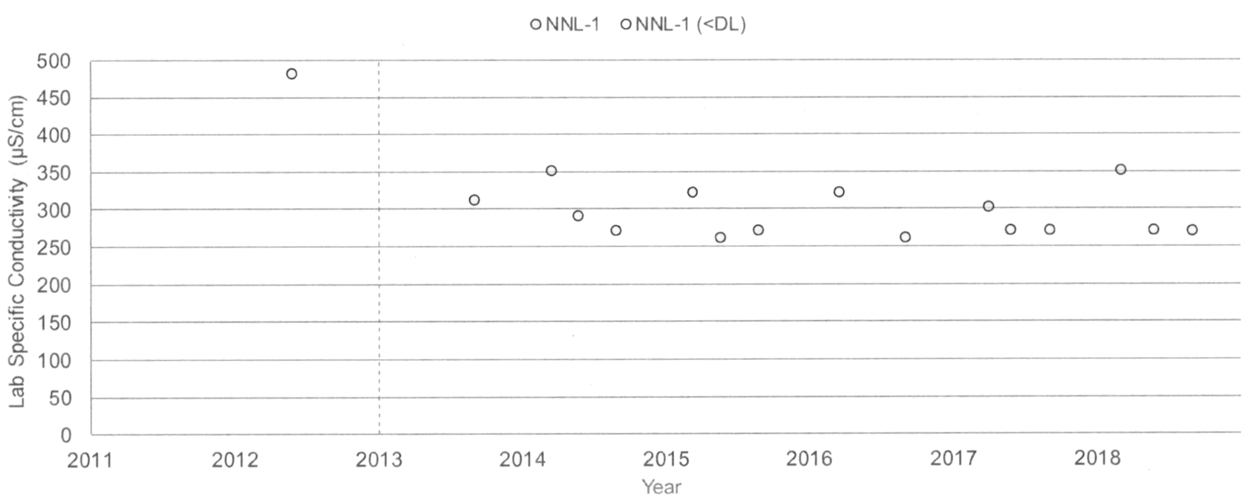
Total phenolics (and/or phenol) concentrations did not show a temporal trend (Figure 4-20; Appendix VII, Table VII-113).

Generally, temporal trends were not identified for total and dissolved metals (Appendix VII). Most metals showed a few high concentrations at some point during construction and early operational phase but did not show a long-term trend. However, there were increasing trends in total aluminium, cobalt, iron, manganese, and titanium concentrations (Figures 4-21, 4-22, 4-23, 4-24, and 4-25) and a decreasing trend was apparent in total and dissolved uranium (Figure 4-26, Appendix VII, Figure VII-164).



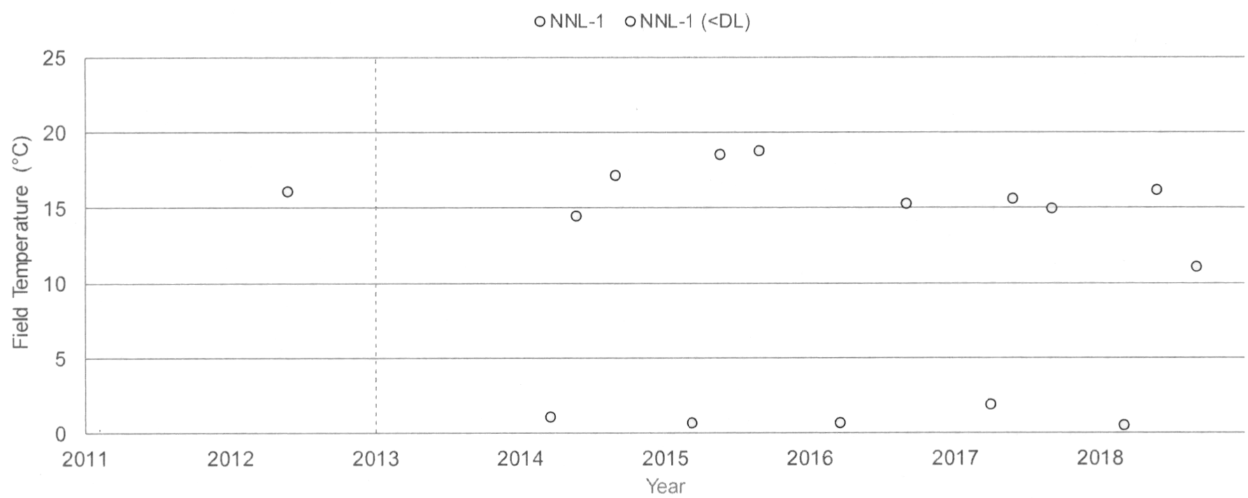
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure 4-12: Time Series Plot at Station NNL-1 for Field Measured Specific Conductivity



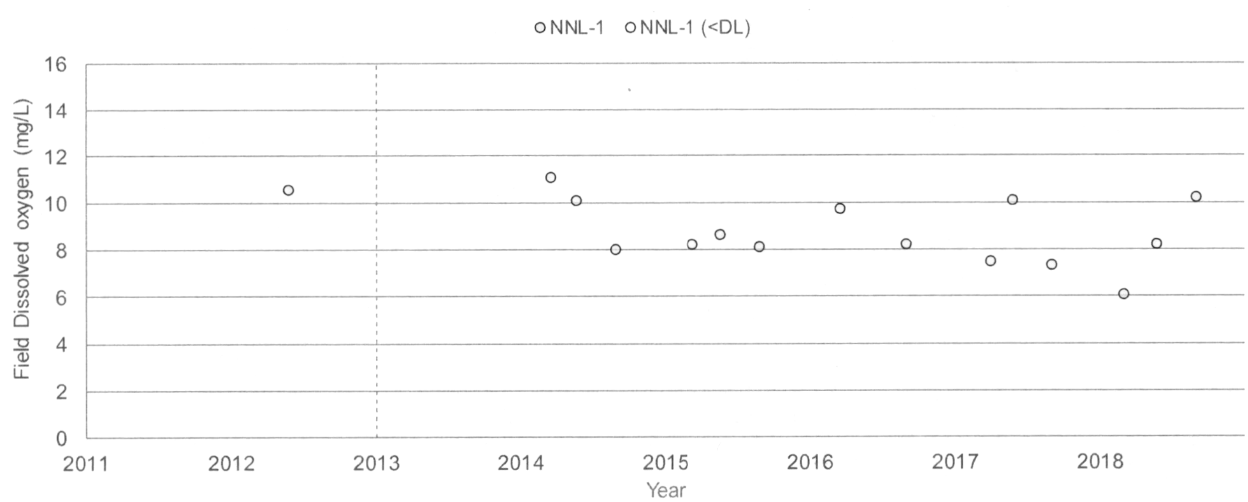
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure 4-13: Time Series Plot at Station NNL-1 for Laboratory Specific Conductivity



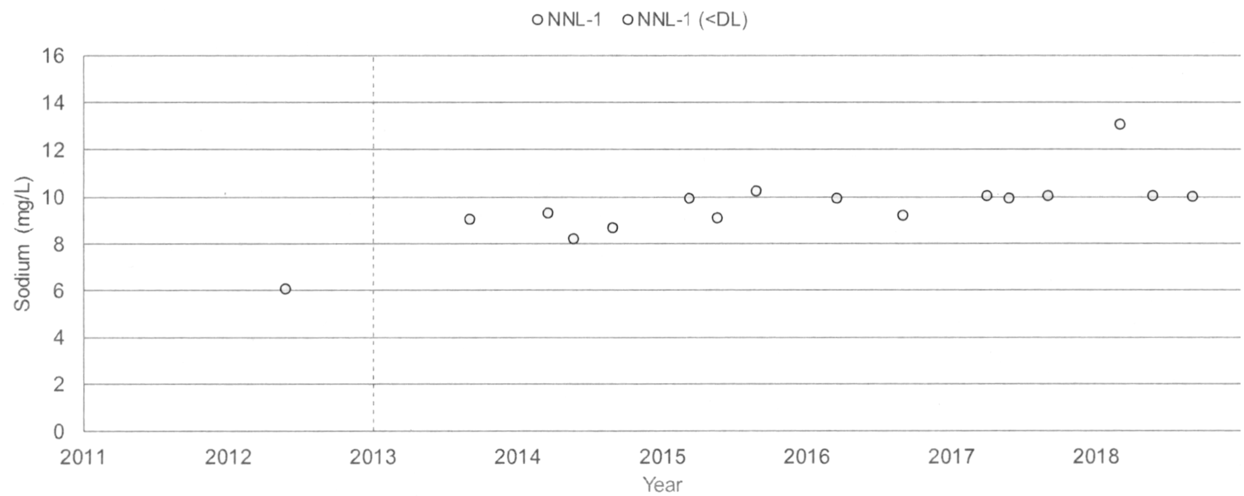
DL = detection limit; < = less than.

Figure 4-14: Time Series Plot at Station NNL-1 for Field Measured Temperature



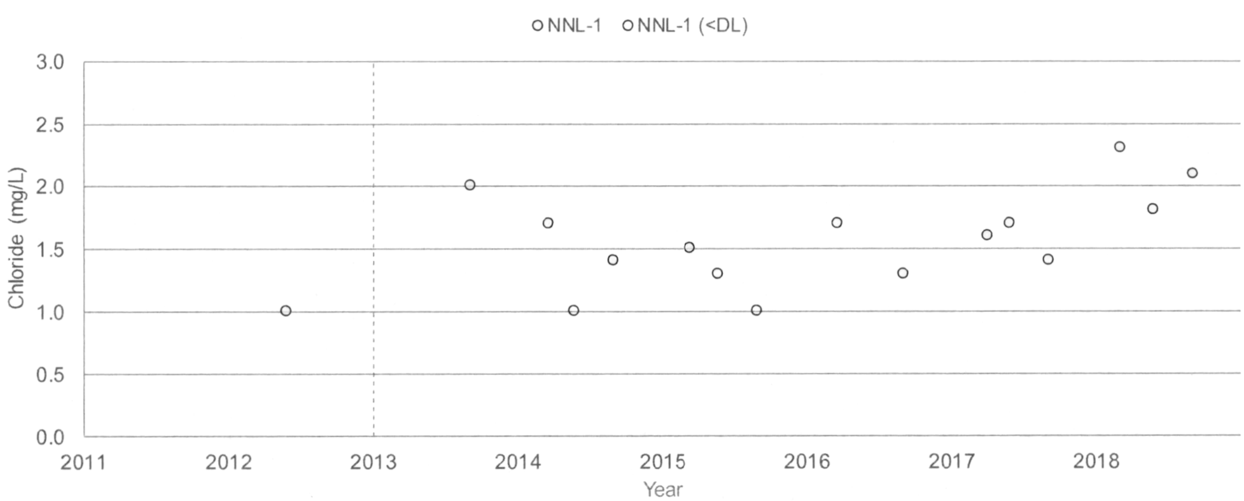
DL = detection limit; < = less than.

Figure 4-15: Time Series Plot at Station NNL-1 for Field Measured Dissolved Oxygen



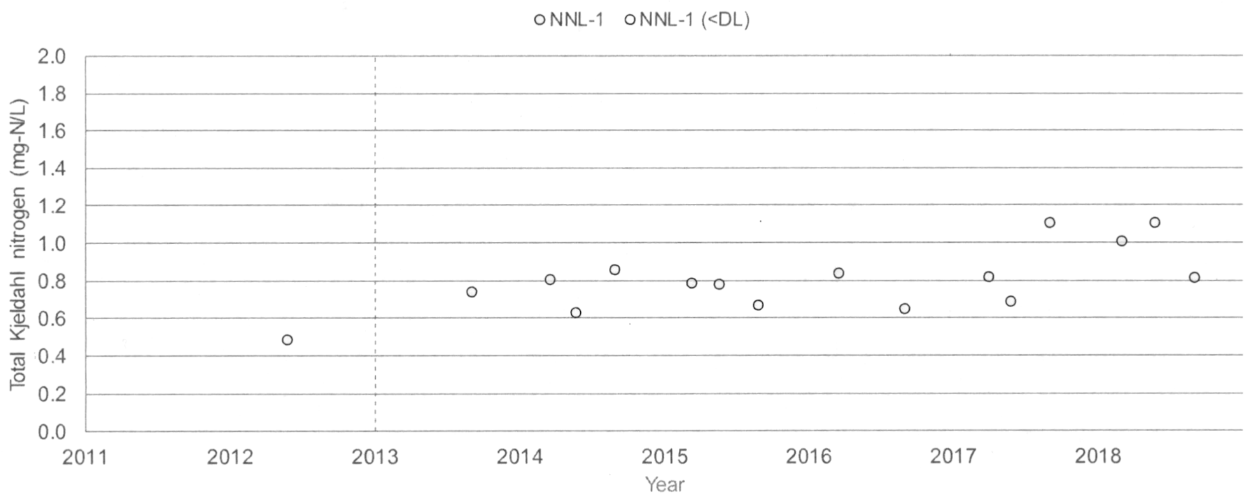
DL = detection limit; < = less than.

Figure 4-16: Time Series Plot at Station NNL-1 for Sodium



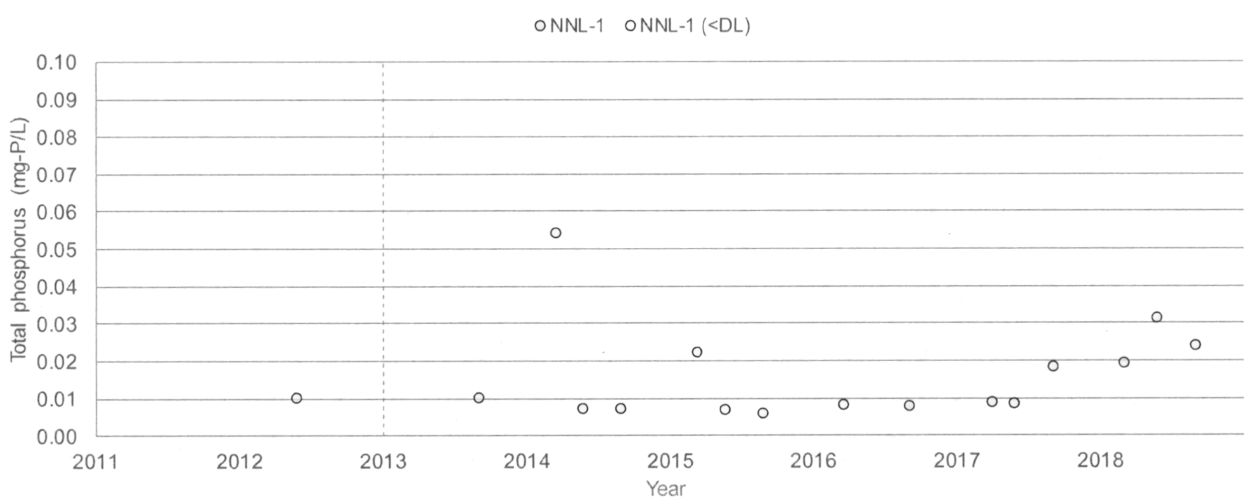
DL = detection limit; < = less than.

Figure 4-17: Time Series Plot at Station NNL-1 for Chloride



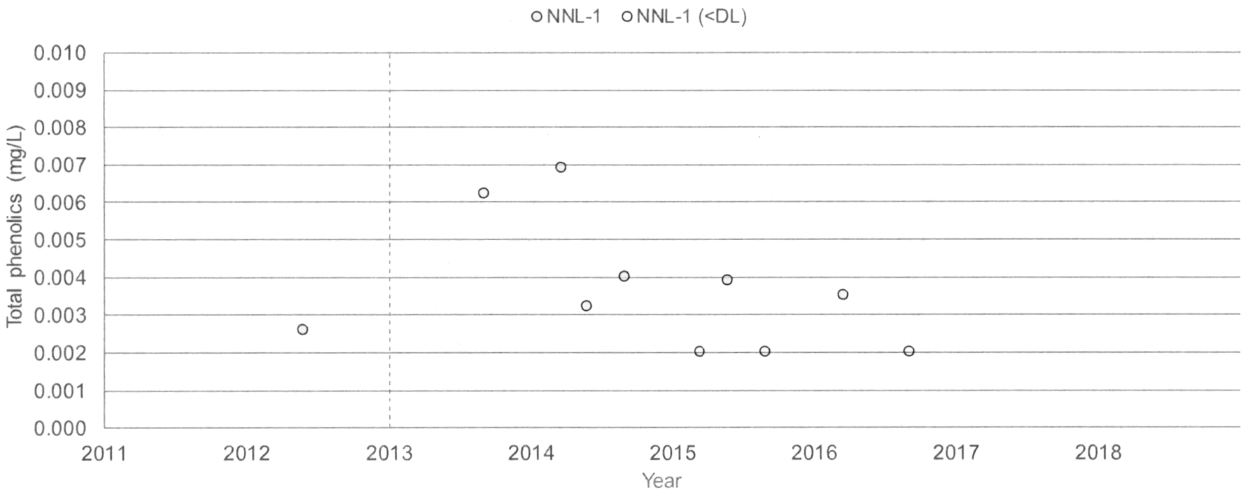
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure 4-18: Time Series Plot at Station NNL-1 for Total Kjeldahl Nitrogen



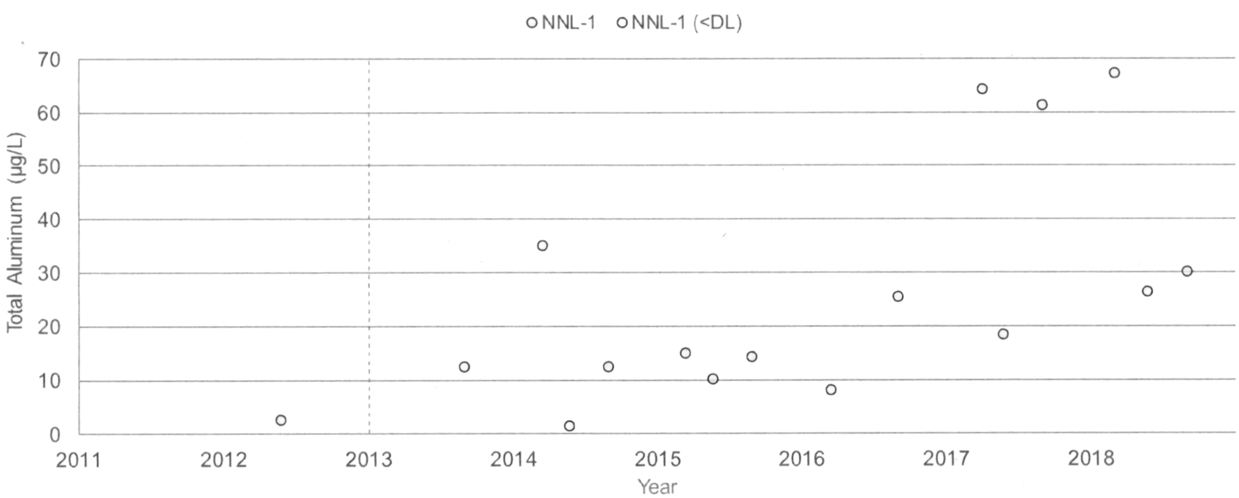
mg-P/L = milligrams as phosphorus per litre; DL = detection limit; < = less than.

Figure 4-19: Time Series Plot at Station NNL-1 for Total Phosphorus



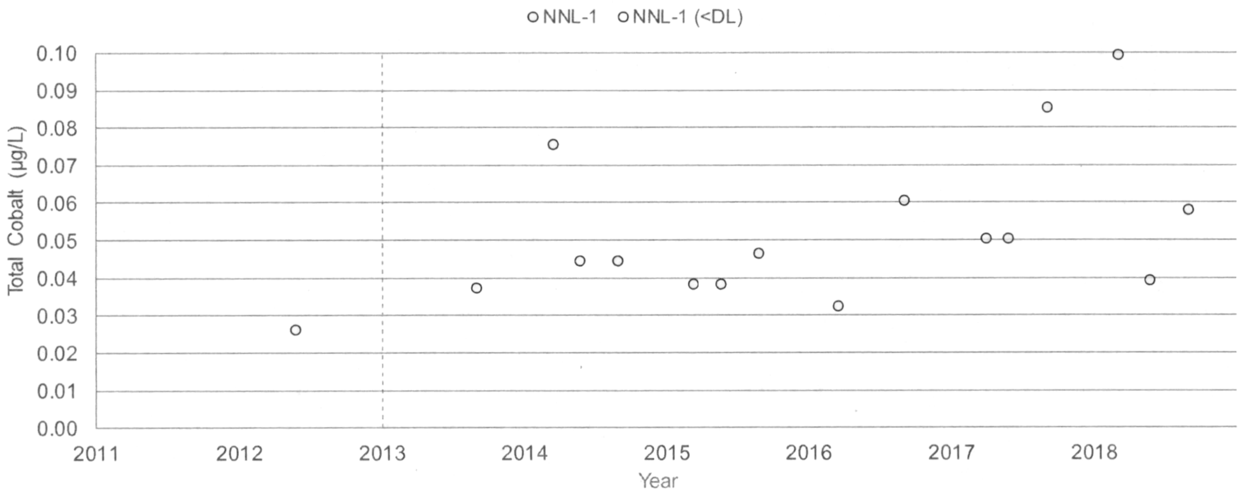
DL = detection limit; < = less than.

Figure 4-20: Time Series Plot at Station NNL-1 for Total Phenolics



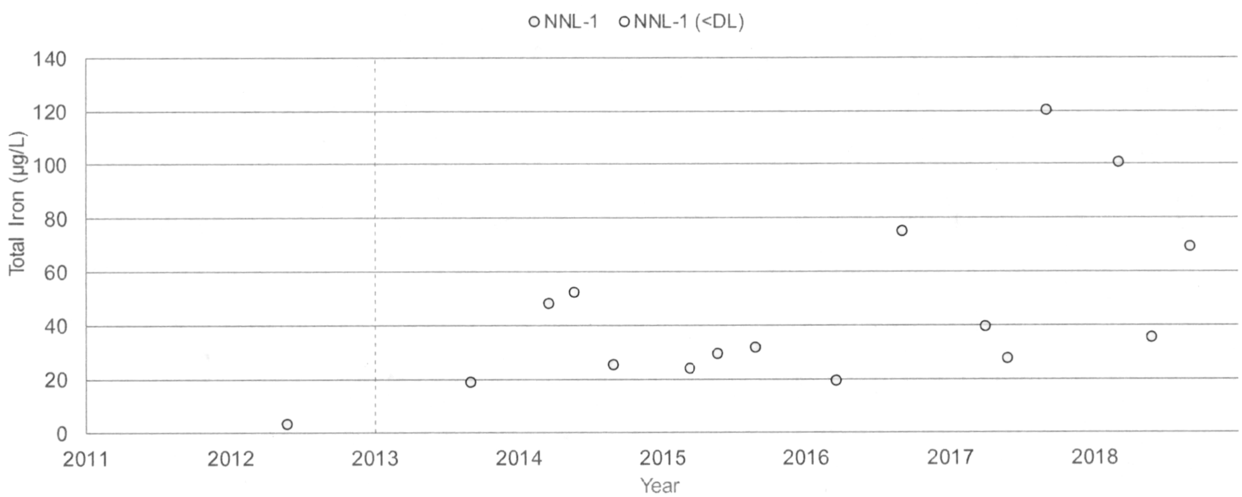
DL = detection limit; < = less than.

Figure 4-21: Time Series Plot at Station NNL-1 for Total Aluminum



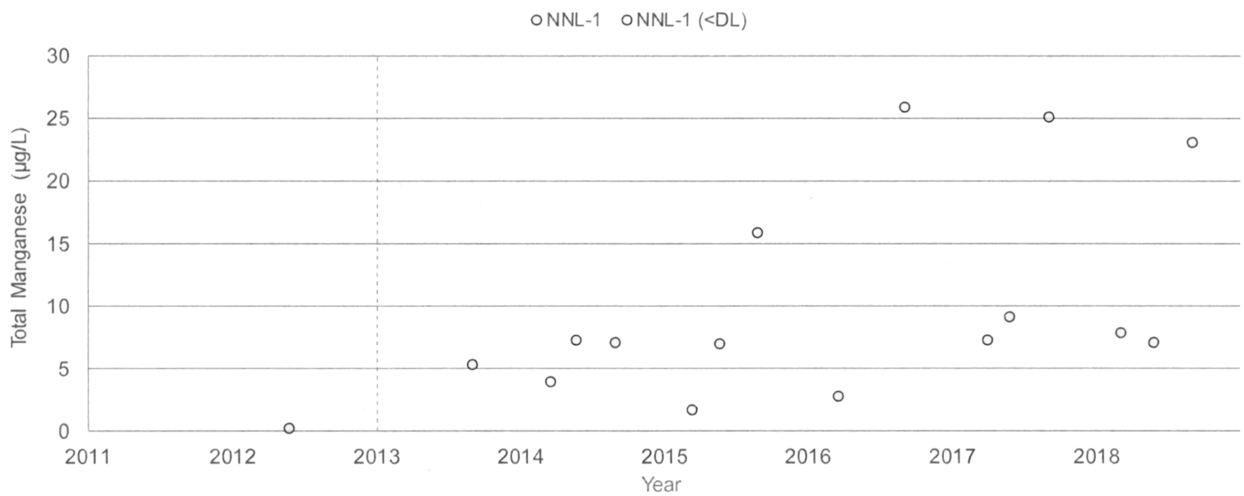
DL = detection limit; < = less than.

Figure 4-22: Time Series Plot at Station NNL-1 for Total Cobalt



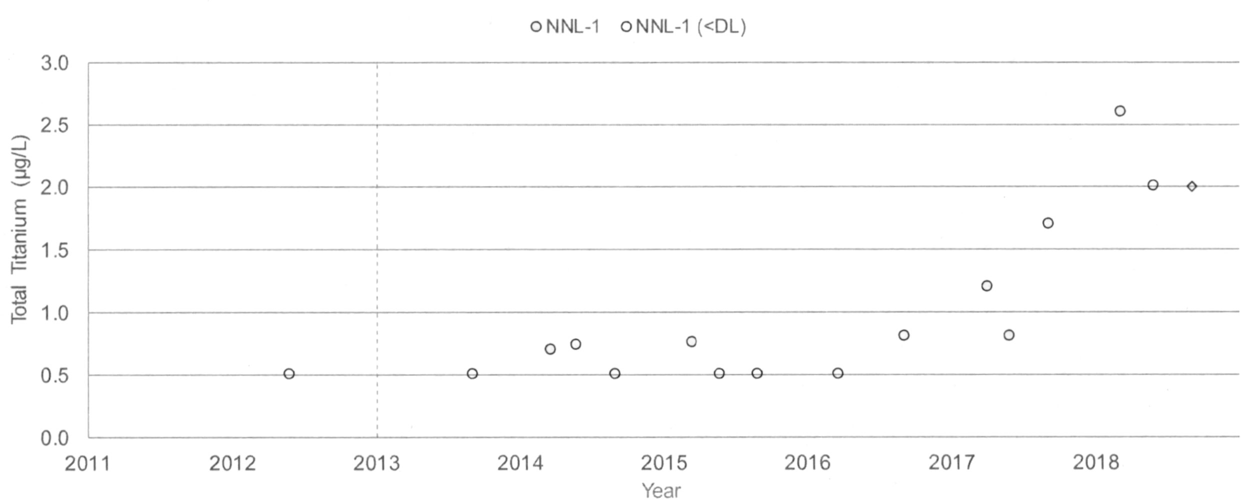
DL = detection limit; < = less than.

Figure 4-23: Time Series Plot at Station NNL-1 for Total Iron



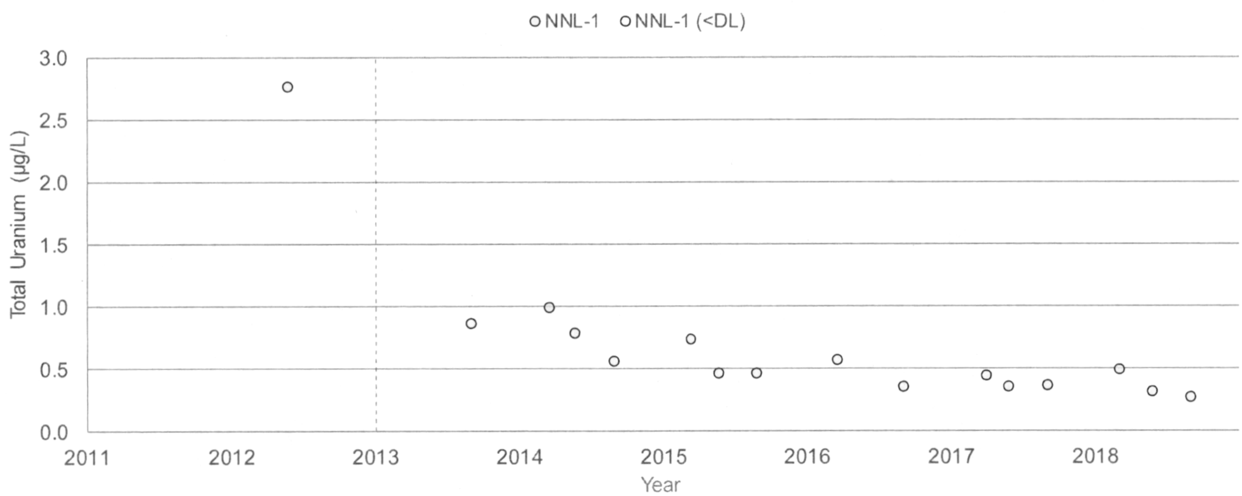
DL = detection limit; < = less than.

Figure 4-24: Time Series Plot at Station NNL-1 for Total Manganese



DL = detection limit; < = less than.

Figure 4-25: Time Series Plot at Station NNL-1 for Total Titanium



DL = detection limit; < = less than.

Figure 4-26: Time Series Plot at Station NNL-1 for Total Uranium

4.9 Comparison of Monitoring Data to Predicted Conditions in Muskeg Lake

Water quality model predictions for Phase I (2007 to 2024) of Muskeg Lake presented in the Kearl NNLP (Imperial Oil 2007) were generally confirmed by the monitoring data collected to date. As expected, the characteristics of Muskeg Lake were usually similar to, or trending towards, Kearl Lake conditions.

4.9.1 Trophic Status

Based on total nitrogen and total phosphorus concentrations measured in late-summer (and spring 2012), the trophic status of Muskeg Lake was categorized as oligotrophic from 2012 to 2016, and mesotrophic in 2017 and 2018 (Table 4-14). This is consistent with model predictions, which indicated that Muskeg Lake would eventually be mesotrophic to meso-eutrophic (Imperial Oil 2007), matching Kearl Lake. As predicted, Muskeg Lake nutrient concentrations were initially less than those measured in Kearl Lake, but became similar to Kearl Lake (i.e., mesotrophic to meso-eutrophic) over time (Tables 4-14 and 4-15) (Imperial Oil 2007).

4.9.2 Water Temperature

Temperature at Muskeg Lake was predicted to be isothermal year-round (Imperial Oil 2007). The monitoring data shows that Muskeg Lake was isothermal during the late summer/early fall, but not during winter and spring in 2018 (Figure 4-27). Winter temperatures throughout the water column at Muskeg Lake showed a similar pattern as Kearl Lake (Figure 4-27); temperature was just above 0^{0}C at the top of the water column and increased to just under 4^{0}C after the first few metres. Muskeg Lake is deeper than Kearl Lake and therefore temperature could not be compared between the two lakes past 2 m depth. From approximately 2 m to the bottom of the water column, temperatures were approximately 4°C in Muskeg Lake, a typical condition in pelagic areas due to water reaching its highest density at 4°C and settling in the lower portion of the lake. In spring Muskeg and Kearl lakes were isothermal (at approximately 16°C) for the first 2 to 3 m, but beyond 3 m depth, temperature decreased steeply, indicating thermal stratification. Both lakes were isothermal during late summer/early fall at approximately 10°C (Figure 4-27). The winter temperature ranges measured in 2018 at Muskeg Lake during the seasonal survey match the winter model predictions (0°C to 3°C). The late summer seasonal temperature measurements were lower in summer (range of 9°C to 11°C) than what was predicted for summer temperatures in Muskeg Lake

(i.e., 15°C to 25°C), as would be expected based on the timing of the survey (i.e., late summer). This pattern occurred in Kearl Lake as well, indicating the two lakes had similar temperature regimes. Section 5.6.3.2 provides a more detailed assessment of summer temperatures based on the datasondes that were deployed for the fish habitat monitoring program.

4.9.3 Dissolved Oxygen

In open-water seasons, stratification was predicted to be negligible and concentrations of dissolved oxygen were predicted to be greater than 7 mg/L (Imperial Oil 2007). Summer 2018 dissolved oxygen measurements showed no indication of oxygen stratification during the summer in Muskeg Lake or Kearl Lake – dissolved oxygen concentrations were always higher than 7 mg/L in Muskeg Lake, as predicted, but not in Kearl Lake (Figure 4-28). In spring, 2018 dissolved oxygen concentrations showed negligible stratification throughout most of the water column in both lakes, but some fluctuation occurred in Muskeg Lake at 4 m; however, dissolved oxygen concentrations were still greater than 7 mg/L throughout the water column. Dissolved oxygen concentrations were highest in late summer/early fall in both lakes in 2018 (approximately 10 mg/L) and lowest in the winter in both lakes (approximately 2 to 6 mg/L and 2 to 3 mg/L in Muskeg Lake and Kearl Lake, respectively), which is consistent with model predictions (Imperial Oil 2007). Concentrations of dissolved oxygen in the late winter were predicted to be 0 mg/L within 1 m of the lake bed in Muskeg Lake and 5 mg/L or higher in the rest of the water column (Imperial Oil 2007).

The annual monitoring data indicates that the dissolved oxygen predictions were accurate for most years, with dissolved oxygen levels of 5 to 11 mg/L in the mid to upper water column, and as low as 0.67 near the lake bed in one year (2017). In 2018 however, dissolved oxygen concentrations were less than 5 mg/L in the mid water column (Figure 4-28), although they were 5 mg/L or higher in the upper water column and were higher than predicted near the lake bed (2.2 mg/L). Overall, dissolved oxygen conditions do not fully match the winter predictions for Muskeg Lake. Additional evaluation of dissolved oxygen levels in Muskeg Lake is provided in Section 5.6.3.4 based on the datasondes that were deployed for the fish habitat monitoring program and the habitat suitability requirements of the fish species present in the lake.

4.9.4 Total Dissolved Solids

Concentrations of TDS in Muskeg Lake ranged from 150 mg/L to 320 mg/L from 2012 to 2018 (Appendix VII, Figure VII-92) but did not show an increasing or decreasing trend. In the NNLP, concentrations of TDS were predicted to increase by about 30 mg/L over the long-term (approximately 200 years) (Imperial Oil 2007). Although no increasing pattern was observed or expected yet, variability in TDS concentrations was observed from 2012 to 2016, after which concentrations stabilized at approximately 200 mg/L (Appendix VII, Figure VII-92). Compared to predictions, concentrations of TDS in Phase I Muskeg Lake were initially more variable than the predicted range of 230 mg/L to 245 mg/L but stabilized at a lower concentration than what was predicted (Imperial Oil 2007). In Kearl Lake, TDS concentrations also did not show a temporal trend (Figure 4-2) and ranged from 100 mg/L to 260 mg/L between 2006 and 2018. Concentrations of TDS in Muskeg Lake were within the range measured at Kearl Lake, with the exception of one higher measurement during the lake filling period (320 mg/L in 2012). Comparable TDS ranges between lakes indicates that Muskeg Lake can be characterized as similar to Kearl Lake. Since lake filling (i.e., excluding 2012), concentrations of TDS in Muskeg Lake were 200 to 250 mg/L in the winter and somewhat lower (150 mg/L to 200 mg/L) in the spring, confirming the prediction that concentrations of TDS would be lower in spring (Imperial 2007).

Table 4-14: Trophic Status and Nutrient Concentrations in Muskeg Lake, 2012 to 2018

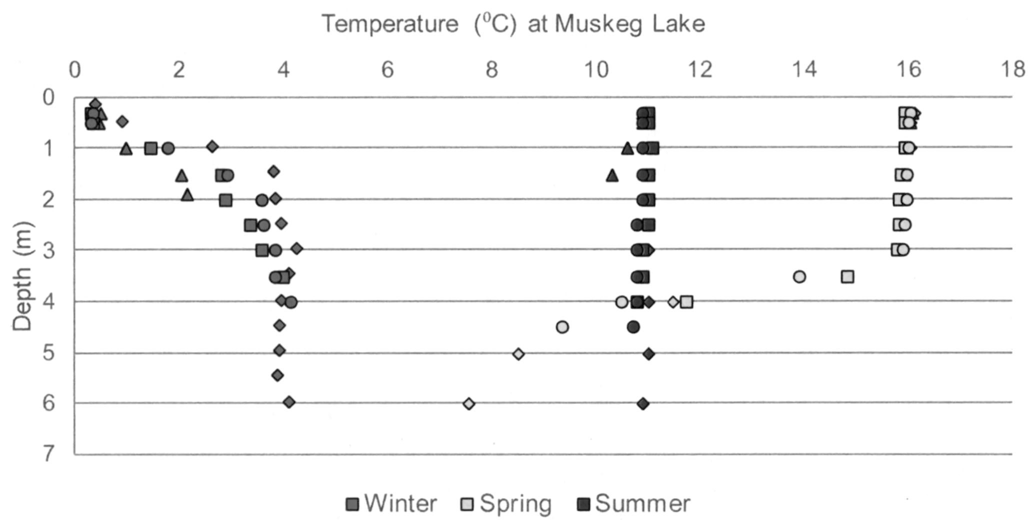
Parameter	Unit	Imperial Sampling Program						
		2012	2013	2014	2015	2016	2017	2018
		May	September	August	August	September	September	September
Physical Parameters								
Secchi Depth	m	2.6	3.2 to 5.3	3.0	2.7	1.8 to 1.9	0.8	1.9
Nutrients								
Nitrate	mg-N/L	<0.003	-	<0.01	<0.01	<0.01	0.017	<0.01
Nitrite	mg-N/L	<0.003	-	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate + nitrite	mg-N/L	<0.003	0.007	<0.01	<0.02	<0.02	0.017	<0.014
Total ammonia	mg-N/L	<0.05	<0.05	0.053	0.11	<0.05	0.025	0.024
Total Kjeldahl nitrogen	mg-N/L	0.48	0.73	0.85	0.66	0.64	1.1	0.81
Total nitrogen[(a)]	mg-N/L	0.48	0.74	0.85	0.66	0.64	1.1	0.81
Total phosphorus	mg-P/L	0.010	0.010	0.007	0.0057	0.0076	0.018	0.024
Dissolved phosphorus	mg-P/L	0.004	0.004	0.003	0.0042	0.0068	0.004	0.0032
Trophic Status[(b)]								
-	-	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic

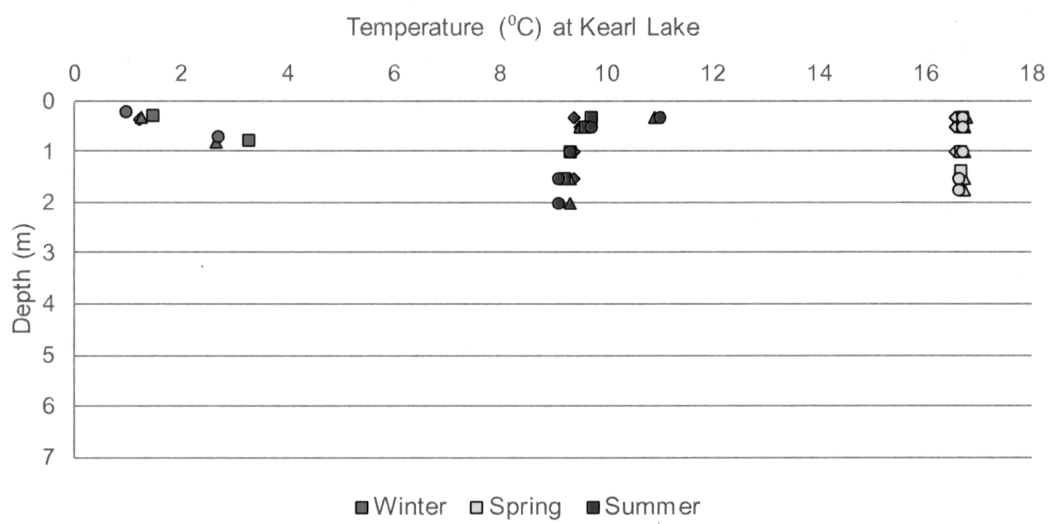
(a) Total nitrogen = (total Kjeldahl nitrogen) + (nitrate + nitrite)
(b) Determined using total nitrogen and total phosphorus concentrations and Secchi depth. Chlorophyll a data were not available.
Note: - = data not available or not applicable; mg-N/L = milligrams of nitrogen per litre; mg-P/L = milligrams of phosphorus per litre; < = less than.

Table 4-15: Trophic Status and Nutrient Concentrations in Kearl Lake, 2012 to 2018

Parameter	Unit	RAM Sampling Program		Imperial Sampling Program				
		2012	2013	2014	2015	2016	2017	2018
		September	September	August	August	September	-[(a)]	September
Physical Parameters								
Secchi Depth	m	-	-	1.0	1.2 to 1.4	1.2 to 1.3	-	1.2
Nutrients								
Nitrate	mg-N/L	0.05	0.05	0.02	<0.01	<0.01	-	<0.01
Nitrite	mg-N/L	0.05	0.05	<0.01	<0.01	<0.01	-	<0.01
Nitrate + nitrite	mg-N/L	0.071	0.071	0.02	<0.02	<0.02	-	<0.014
Total ammonia	mg-N/L	0.05	0.05	0.065	<0.05	<0.05	-	0.022
Total Kjeldahl nitrogen	mg-N/L	1.25	0.93	0.77	0.79	0.61	-	1.1
Total nitrogen[(b)]	mg-N/L	1.32	1.00	0.79	0.79	0.61	-	1.1
Total phosphorus	mg-P/L	0.0202	0.0315	0.0100	0.0260	0.0140	-	0.0450
Dissolved phosphorus	mg-P/L	0.0074	0.0079	0.0040	0.0089	0.0073	-	0.0027
Trophic Status[(c)]								
-	-	Mesotrophic	Mesotrophic	Oligotrophic	Mesotrophic	Oligotrophic	-	Mesotrophic

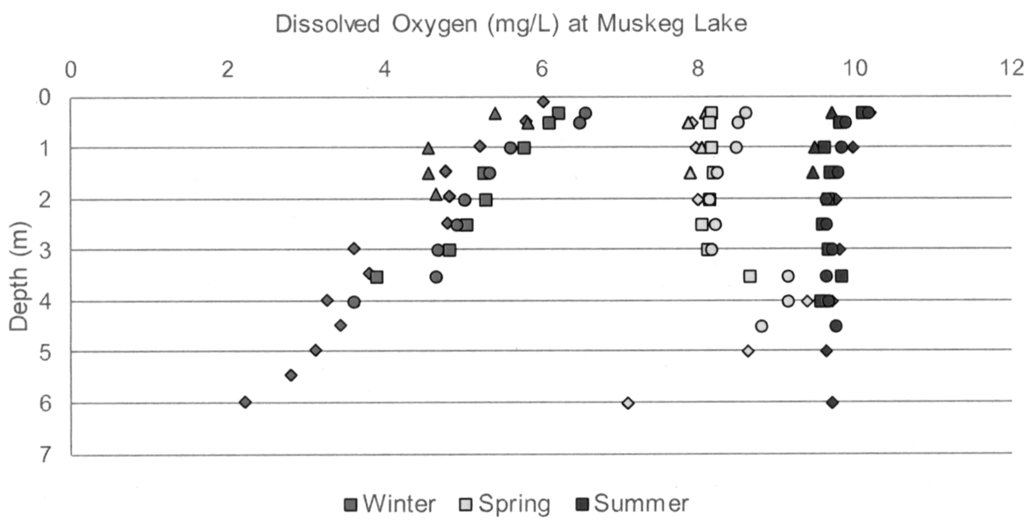
(a) Sample not collected due to bear activity in the sampling area.
(b) Total nitrogen = (total Kjeldahl nitrogen) + (nitrate + nitrite).
(c) Determined using total nitrogen and total phosphorus concentrations and Secchi depth. Chlorophyll a data were not available.
Note: RAM = Regional Aquatics Monitoring; - = data not available or not applicable; mg-N/L = milligrams of nitrogen per litre; mg-P/L = milligrams of phosphorus per litre; < = less than.

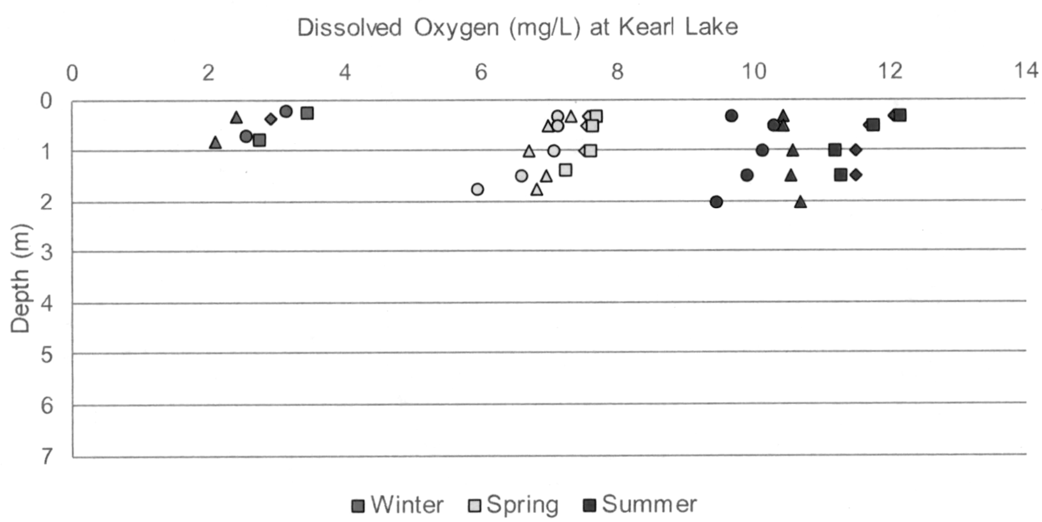




Note: Different shaped markers represent replicate temperature profiles measured during each program.

Figure 4-27: Temperature Profiles in Muskeg and Kearl Lakes in 2018





Note: Different shaped markers represent replicate temperature profiles measured during each program.

Figure 4-28: Dissolved Oxygen Profiles in Muskeg and Kearl Lakes in 2018

5.0 FISH AND FISH HABITAT PROGRAM

5.1 Fish and Fish Habitat Monitoring Program Overview

As per the long-term SWFM Plan (Imperial Oil 2009a), the fish and fish habitat component of the 2018 monitoring program consisted of the following activities designed to collect fish habitat and fish population data for evaluating the biological development of Muskeg Lake, and data for assessing fish populations in Kearl Lake following 5 years of connection to Muskeg Lake.

- Collect habitat data in Muskeg Lake relative to assessing habitat development and lower-level productivity (i.e., key water quality parameters, macrophyte distribution, plankton sampling and benthic invertebrate sampling).
- Conduct a habitat-based fisheries inventory in Muskeg Lake to assess species colonization, composition, abundance and biomass.
- Conduct a fisheries inventory in Kearl Lake to assess species composition, abundance and biomass.

Muskeg Lake (Station NNL-1) and Kearl Lake (Station KEL-1) were the only fish and fish habitat monitoring stations in 2018 (Figure 2-1, Table 5-1). Two monitoring surveys were completed, a spring survey and a late summer survey. The 2018 survey dates were: 25 to 30 May (spring), and 29 August to 4 September (late summer). Data concerning winter habitat conditions (e.g., late winter dissolved oxygen levels) were obtained from the results of the late winter survey conducted for the water quality program (7 March).

Sampling of Muskeg Lake was conducted at representative locations within the waterbody. Habitat parameters (i.e., in-situ water quality profile measurements) and plankton sampling was conducted at the deepest location in the lake. Continual in-situ water quality parameter monitoring was conducted by installing two data loggers – one each in the littoral (i.e., ≤3 m deep) and pelagic (i.e., >3 m deep) zones. Aquatic vegetation mapping was conducted for the littoral zone. Benthic invertebrate sample collection was conducted in both the littoral and pelagic zones. Fish sampling was conducted for the lake in general (gill-netting), or by individual meso-habitat (minnow trapping and portable boat electrofishing).

Table 5-1: Fish and Fish Habitat Monitoring Station, 2018

Station	Watercourse or Waterbody	Habitat Category	Description	UTM Coordinates (Centre of Waterbody)	
				Easting	Northing
NNL-1	Muskeg Lake	Compensation	Phase I Compensation Lake	486900	6351832
KEL-1	Kearl Lake	Natural	Connected to Muskeg Lake	485572	6349749

Note: See Figure 2-1 for station location; UTM = Universal Transverse Mercator Coordinates, North American Datum (NAD) 1983, Zone 12.

Sampling of Kearl Lake for fish population data was conducted in representative littoral habitats throughout the lake, as this lake consist entirely of shallow littoral habitat.

Monitoring activities conducted in 2018 for Muskeg Lake and Kearl Lake comply with the long-term SWFM Plan (Imperial Oil 2009a). The 2018 monitoring activities are listed in Table 5-2 and monitoring details are presented in Section 5.2.

For Muskeg Lake, habitat-based sampling was completed throughout the lake for the portion of the fish sampling program that was conducted by minnow trapping. Minnow traps were deployed into the different meso-habitats in Muskeg Lake to sample for small-bodied forage fish and smaller life stages (fry, juvenile) of large-bodied fish. Identification and descriptions for the meso-habitat types in the Muskeg Lake (Table 5-3) were based on the habitat types presented in the species-specific fish habitat suitability index (HSI) models that were developed for use in the oil sands region (Golder 2008), and which were used in the design of Muskeg Lake. Large-bodied fish sampling by gill netting was conducted throughout the lake to determine species composition. Supplemental portable boat electrofishing passes were conducted in the shallow meso-habitats in Muskeg Lake in the late summer to sample for small and large-bodied fish. Fish sampling methods are present in Section 5.2.5.

Table 5-2: Fish and Fish Habitat Monitoring Activities by Season, 2018

Activity	Season	Muskeg Lake (Station NNL-1)	Kearl Lake (Station KEL-1)
Habitat Suitability Index Variables (in-situ water quality)	Winter	√ (profile)	-
	Spring	√ (profile)	√
	Late Summer	√ (profile)	√
	Continual (spring through late summer)	√ (datalogger)	-
Aquatic Macrophytes	Late Summer	√	-
Plankton	Late Summer	√	-
Benthic Invertebrates	Late Summer	√	-
Fish Populations	Spring	√	√
	Late Summer	√	√

Note: √ = monitoring conducted in 2018; - = monitoring not planned/conducted.

Table 5-3: Muskeg Lake Meso-Habitat Definitions, 2018

Meso-Habitat Type	Meso-Habitat Description
A	Shallow Littoral (0 to 2 m deep) with fine substrate and no cover
B	Shallow Littoral (0 to 2 m deep) with fine substrate and moderate to high density aquatic macrophyte cover
C	Shallow Littoral (0 to 2 m deep) with fine substrate and large woody debris cover
D	Shallow Littoral (0 to 2 m deep) with gravel/cobble substrate
E	Deep littoral to mid pelagic (>2 to 5 m deep) with fine substrate and no cover
F	Deep littoral to mid pelagic (>2 to 5 m deep) with gravel/cobble substrate
G	Deep littoral to mid pelagic (>2 to 5 m deep) with fine substrate and boulder garden cover
H	Deep littoral to mid pelagic (>2 to 5 m deep) with fine substrate and large woody debris cover
I	Deep pelagic (>5 to 7 m deep) with fine substrate and no cover

Note: >= greater than; m = metres.

5.2 Monitoring Methods

The monitoring methods are described below for each of the 2018 monitoring activities identified in Table 5-2.

5.2.1 Habitat Suitability Data

The collection of data for habitat suitability analysis was done at representative locations in Muskeg Lake (Station NNL-1). Data collection involved the habitat variables (i.e., physical habitat and physio-chemical parameters) that have been identified as being determinants of fish habitat suitability for the fish species known, or assumed, to be present in the monitored habitats, based on the habitat suitability index (HSI) models developed for use in the oil sands region (Golder 2008). Data collection for habitat suitability index variables occurred on a seasonal or continuous basis, as appropriate for the relevant habitat variables. Seasonal data were collected during the spring and late summer surveys for Muskeg Lake, while continuous data were collected from spring to late summer using dataloggers. Some of the variables for habitat suitability analysis were collected in Muskeg Lake as part of the macrophyte assessment (Section 5.2.2).

Physio-chemical parameters, (i.e., water temperature, dissolved oxygen, pH and conductivity) were measured as part of the habitat suitability assessment. Profile data were collected during the seasonal surveys by in-situ measurements of water quality parameters along a vertical profile. At a minimum, one profile was collected per season at the deepest part of Muskeg Lake, with additional profiles completed at various locations in the lake during the late summer survey. Profile measurements were completed using an YSI Model 556 multi-parameter water quality meter.

In addition to seasonal measurements in Muskeg Lake, continuous measurements are needed to better define the ranges and temporal distribution of the relevant water quality data in order to provide the inputs for the HSI models. Some of the species-specific models also require monitoring in both the littoral and pelagic zones of the lake. To collect continuous data, two Aqua-Troll 600 multi-parameter water quality dataloggers (datasondes) were installed in Muskeg Lake during the spring survey – one at 1.5 m below the surface in the littoral zone (water 3.0 m deep), and one at 4.0 m below the surface in the pelagic zone (water 6.6 m deep). The datasondes were set to record measurements every hour and were left in place until the late summer survey. The pelagic datasonde provided a continuous record for the period of deployment. However, due to logger malfunction, the littoral datasonde stopped recording data a few days after being deployed and data could not be extracted from the logger.

5.2.2 Aquatic Macrophytes

At the Muskeg Lake monitoring station (NNL-1), mapping of the distribution of aquatic macrophytes was conducted throughout the littoral zone, where plants could be observed from the surface. The following macrophyte parameters were recorded:

- average cover (%);
- plant type (submergent or emergent); and
- dominant species/genera.

Photographs were taken at Muskeg Lake to show general habitat conditions, including shoreline and riparian areas, and the connector channel to Kearl Lake.

5.2.3 Plankton

Plankton sampling was conducted at the Muskeg Lake monitoring station (NNL-1) to help provide a measure of developing lake productivity. Plankton samples were collected to characterize the plankton communities (phytoplankton and zooplankton) in terms of community composition, taxonomic richness, abundance (density) and biomass. Zooplankton and phytoplankton samples were collected during the late summer survey. Three zooplankton and three phytoplankton samples were collected from the lake, one from each of three representative sampling sites in the deepest portion of the lake. At each of the three sampling sites, a composite sample was obtained by collecting a number of samples, which were combined to form a single sample. The three composite samples were analyzed separately to determine mean values for the lake.

Phytoplankton samples were collected from the euphotic zone (i.e., zone of light penetration defined as two times the Secchi depth) using a Van Dorn water sampling bottle with a sampling volume of 2.2 L (Table 5-4). Each of the three composite samples consisted of water collected from regular depths (0.7 m intervals) throughout the euphotic zone. The discrete water samples collected from each depth interval were combined in a large sample container to provide a single depth integrated sample. A one-litre sample was collected from each composite sample and preserved with Lugol's solution (3 mL).

Table 5-4: Summary of Phytoplankton Sample Collection in Muskeg Lake, 2018

Location	Replicate	Secchi Depth (m)	Depth of Euphotic Zone (m)	Number of Grabs per Replicate	Grab Depths (m)	Amount of Water Collected per Grab (L)
Deepest Portion of Lake (6.7 m)	1	1.9	3.8	5	0.7, 1.4, 2.1, 2.8, 3.5	2.2
	2	1.9	3.8	5	0.7, 1.4, 2.1, 2.8, 3.5	2.2
	3	1.9	3.8	5	0.7, 1.4, 2.1, 2.8, 3.5	2.2

Note: m = metres; L = liters.

Zooplankton samples were collected using a 25 cm diameter, 74 µm mesh Wisconsin plankton net with a sampling area of 0.049m^2. Each of the three composite samples consisted of two vertical plankton net hauls that were performed at each sampling site and combined to form a single composite sample. Each individual haul was conducted by hauling the plankton net vertically through the water column at a rate of approximately 0.5 m/s. The total distance hauled was recorded for each haul and used to calculate the volume of water filtered through the net per haul (i.e., haul distance [m] x sampling area [m^2] = lake volume filtered [m^3]; Table 5-5). Samples from the two hauls were combined in one sample container and preserved with half an Alka-Seltzer tablet and 5% buffered formalin solution.

Table 5-5: Summary of Zooplankton Sampling in Muskeg Lake, 2018

Location	Replicate	Number of Hauls	Plankton Net Mouth Diameter (m)	Plankton Net Mouth Area (m^2)	Length per Haul (m)	Lake Volume Filtered per Haul (m^3)	Total Lake Volume Filtered per Sample (m^3)
Deepest Portion of Lake (6.7 m)	1	2	0.25	0.049	5.7	0.279	0.558
	2	2	0.25	0.049	5.7	0.279	0.558
	3	2	0.25	0.049	5.7	0.279	0.558

Note: m = metres; m^2= metres squared; m^3 = cubic metre.

Plankton samples were submitted to an independent laboratory (Maxxam Analytics) for analysis of taxonomic composition and abundance (identification and enumeration to the lowest practical taxonomic level) and estimates of biomass. Counts of organisms were converted to abundance based on the volume of lake sampled (i.e., number of organisms per m^3 for zooplankton and number of organisms per L for phytoplankton). Some analyses were limited to common plankton taxa to reduce the data complexity – common plankton taxa were defined as taxa that accounted for 4% or more of the total biomass.

This report includes the plankton data for samples collected in 2017 and 2018 at Muskeg Lake, as the 2017 data was not available for inclusion in the 2017 Annual Monitoring Report (Golder 2017). A summary of available plankton sampling results to date for Muskeg Lake are included in the summary of the current biological development of the lake (Section 5.4).

5.2.4 Benthic Invertebrates

Benthic invertebrate samples were collected during the late summer survey at Muskeg Lake (Station NNL-1) to monitor the colonization and development of benthic invertebrate communities. All sampling locations in Muskeg Lake were designated as depositional habitat based on the dominant substrate type present (i.e., sampling avoided local areas of rocky substrate).

Benthic invertebrate samples were collected in the depositional habitats using an Ekman grab with a 0.023 m^2 sampling area. Ekman grab samples were sieved in the field using a 250 µm mesh sieve to remove fine sediments. Three replicate grab samples were collected at each of two sampling locations, one in the littoral zone (water depth <3 m) and one in the pelagic zone (water depth >3 m). All samples were subsequently preserved in 10% buffered formalin. The samples were analyzed separately and used to provide an indication of invertebrate colonization and to compare littoral and pelagic areas of the lake.

Benthic invertebrate samples were submitted to an independent laboratory (Maxxam Analytics) for analysis of taxonomic composition and abundance (identification and enumeration to the lowest practical taxonomic level) of invertebrates. Benthic invertebrate taxa and abundance data were then tabulated for all sites and replicate samples. Terrestrial and non-benthic invertebrates, if any, were excluded from the data summary. Counts of individual organisms (numbers per sample) were converted to density (number per m^2) using the sampling area of the Ekman Grab. Benthic invertebrate community summary variables were then calculated for each site, including taxa relative abundance and density, total invertebrate abundance and density, and total taxonomic richness (number of taxa). Some analyses were limited to the common benthic invertebrate taxa to reduce the data complexity. For interpretation purposes, common benthic invertebrate taxa for each site were defined as taxa that accounted for 1% or more of the total number of organisms recorded.

Benthic invertebrate densities and taxonomic richness values were categorized based on regional benthic invertebrate community data, as follows:

- *Low*: mean total density <5,000 organisms/m^2; richness <10 taxa/site;
- *Moderate*: mean total density ranging from 5,000 to 50,000 organisms/m^2; richness ranging from 10 to 40 taxa/site; and
- *High*: mean density >50,000 organisms/m^2; richness >40 taxa/site.

The benthic invertebrate data were also analyzed for community diversity by calculating the following two indices.

1) Simpson’s index of diversity

$$D = 1 - \sum_{i=1}^{S} (p_i)^2$$

where: D = Simpson’s index of diversity;

S = the total number of taxa; and

p_i = the proportion of the ith taxon.

2) Evenness index

$$E = 1/ \sum_{i=1}^{S} (p_i)^2 / S$$

where: E = Evenness;

p_i = the proportion of the ith taxon; and

S = the total number of taxa.

For the diversity and evenness indices, a value of 1 indicates high diversity/evenness and 0 indicates low diversity/evenness. Ranges of diversity/evenness values were categorized as follows:

- *Low*: <0.25
- *Moderate*: 0.25 to 0.75; and
- *High*: >0.75

This report includes the benthic invertebrate taxonomy results for samples collected in 2017 and 2018 at Muskeg Lake, as the 2017 results were not available for the 2017 Annual Monitoring Report. A summary of available benthic invertebrate sampling results to date for Muskeg Lake are included in the summary of the current biological development of the lake (Section 5.4).

5.2.5 Fish Populations

5.2.5.1 Muskeg Lake

Fish population sampling in Muskeg Lake (Station NNL-1) was conducted to provide an indication of natural colonization of the lake by fish species from Kearl Lake and the level of fish population development by the fifth year after the connector channel between the two lakes was opened. At this stage in the Muskeg Lake monitoring program, when forage fish populations have established but some large-bodied fish populations are in the process of colonization, the sampling program concentrated on sampling for forage fish. Therefore, specific meso-habitat based sampling was conducted using minnow traps to test for abundance and biomass levels for each forage fish species, while other sampling techniques (i.e., gill netting and boat electrofishing) were conducted in representative locations in the lake to test for presence and abundance of large-bodied fish.

For Muskeg Lake, sampling for fish in the spring was conducted to provide a general fish inventory for species presence and abundance following the spring migration and spawning period. Minnow trapping was the main sampling technique and was conducted in key forage fish habitats (i.e., shallow littoral habitats – meso-habitat types A, B and C in Table 5-3). Gill netting was conducted in representative locations and included littoral and pelagic habitats. Due to the presence of northern pike in Muskeg Lake in previous years, boat electrofishing was not conducted in the spring due to the condition of the Fish Research Licence provided by AEP to avoid electrofishing during the spawning period for this species.

Fish sampling in the late summer in Muskeg Lake was conducted to provide a habitat-based inventory of species composition, abundance and relative biomass. Minnow trapping was the main sampling technique and was conducted separately in all meso-habitats identified in Table 5-3. Gill netting was conducted in representative locations and included littoral and pelagic habitats. Boat electrofishing was conducted in representative shallow littoral habitats where the water depth was 1.5 m or less.

In both seasons, minnow trapping (using standard Gee minnow traps baited with dry cat food) was used as a sampling technique specific to the capture of forage fish and smaller life stages of large-bodied species. For each sampling day, a total of 48 traps were set in six clusters (8 traps/cluster) and left to sample for a minimum of 4.3 hours per set. All minnow trapping effort was recorded per meso-habitat as the number of traps set multiplied by the soak time to provide the number of trap-hours.

Gill netting was conducted in Muskeg Lake to sample various habitats for large-bodied fish in both sampling seasons. Gill netting was conducted using one standardized multi-panel FWIN gill net left to sample for a minimum of 4.3 hours per set and checked at a minimum of every 2 to 3 hours to prevent fish mortality. The gill net consisted of eight panels of different mesh size (i.e., 2.54, 3.81, 5.08, 6.35, 7.62, 10.16, 12.70 and 15.24 cm – stretch measure). Each panel was 7.6 m long and 1.8 m deep, for a total net length of 60.8 m. Four daytime gill net sets were completed during the spring survey, and four gill net sets during the late summer survey the – the sampling licence provided by AEP specified only one gill net to be set per day and no overnight sets. Gill net sampling effort was recorded for each net set as the number of hours of soak time to provide the number of net-hours.

The number of fish of each species captured at each sampling location was recorded by sampling technique. All individuals of large-bodied species were measured for fork length and weight, and the sex, life stage (i.e., fry, juvenile, adult) and state-of-maturity (e.g., pre-spawning, ripe, spent) were also recorded where discernible from external examination. Forage fish were measured individually for length and weight to a minimum of 30 individuals per species. All forage fish not measured individually were measured for batch weight by species, recording the number of fish in the batch and the total weight. The fish weight data was used to calculate total biomass and mean weight per species.

Single-pass boat electrofishing in shallow littoral habitats along portions of the shoreline was completed during the late summer survey in Muskeg Lake. Boat electrofishing was conducted using a Smith-Root Model GPP 2.5 boat electrofisher operated from a 3.8 m inflatable boat (Zodiac) and equipped with two front-mounted anode booms with multiple-cable dropper arrays, and two side-mounted cathode booms with multiple-cable dropper arrays. Electrofishing sampling effort was recorded as the number of seconds of active electrofishing, defined as the seconds that electrical current was applied to the water.

The sampling effort and catch data were used to calculate catch-per-unit-effort (CPUE) for each seasonal sampling period as a measure of abundance. The CPUE was calculated for minnow trapping as the number of fish captured per trap hour, for gill netting as the number of fish captured per net-hour, and for electrofishing as the number of fish per 100 seconds of active electrofishing. The CPUE results were used to represent abundance to allow comparison of catch rates between meso-habitats, seasonal sampling events and monitoring years. As part of the summary of the current biological development of the lake (Section 5.4), CPUE results were also used to compare fish population development in Muskeg Lake to fish populations in other waterbodies in the oil sands region for which CPUE data is also available.

The sampling and catch data were also used to calculate biomass-per-unit-effort (BPUE) as a measure of relative biomass. BPUE calculations were completed by multiplying the CPUE values for each species by the average fish weight for the species, as determined by the individual and batch weight measurements. The BPUE results were used to represent relative biomass to allow comparison of biomass between meso-habitats, seasonal sampling events and monitoring years.

A mark-recapture test study was conducted in Muskeg Lake during the late summer minnow trapping program using a dye marker to evaluate the suitability of this method in providing population estimates and biomass densities by meso-habitat for future evaluation of the biomass of the lake. A biological red dye (N7005 Sigma-Aldrich) was used to mark forage fish captured in each meso-habitat. The dye was used at a concentration of 1:20,000, which is equivalent to 1 gram of dye per 20 litres of water. Captured fish were place in the dye for a minimum of fifteen minutes before being released back to the meso-habitat from which they were captured. Recaptured marked fish were recorded by meso-habitat type and released back to the same meso-habitat.

Population parameters were analyzed by species for Muskeg Lake as a whole. Condition factor was calculated for all fish individually measured for fork length and weight using the standard Fulton-type condition factor formula:

$$\text{Condition Factor} = (\text{weight [g]} \times 10^5) \div (\text{fork length [mm]})^3.$$

Length-frequency plots were completed for forage fish species where a minimum of 30 individuals were captured and measured, and for all large-bodied-fish species regardless of catch numbers. Average fish weights were calculated for each species captured. Size-at-maturity and age-at-maturity plots were also specified in the long-term monitoring plan based on internal examinations of incidental sampling mortalities; however, no mortalities occurred during sampling in 2018.

In order to provide quality assurance and quality control (QA/QC) of fish data, potential outliers were identified as condition factor values falling outside of the first and third quartile of fish measured per species per station. Potential outliers were confirmed visually if they were not consistent with the linear relationship observed when plotting the logarithmic length versus weight of individuals measured. Confirmed outliers were excluded from length frequency analysis, average weight calculations and biomass calculations, but the fish were included in catch numbers and CPUE calculations.

A summary of available fish population sampling results to date for Muskeg Lake are included in the summary of the current biological development of the lake (Section 5.4).

5.2.5.2 Kearl Lake

Fish population sampling in Kearl Lake (Station KEL-1) was conducted to provide data for comparison to previous data for the lake obtained during the five-year baseline sampling program that was conducted from 2009 to 2013 (Golder 2013a), prior to Kearl Lake being connected to Muskeg Lake. Sampling was conducted in Kearl Lake in 2018 as it represents five years since the baseline program was completed. Fish inventory surveys were completed to evaluate if the connection to the secure overwintering habitats in Muskeg Lake provide a benefit to the fish populations in Kearl Lake. Sampling was conducted in the spring and late summer using minnow trapping and gill netting in representative locations in the lake to test for fish presence and abundance.

For Kearl Lake, sampling for fish in the spring was conducted to provide a general fish inventory for species presence and abundance during the spring migration and spawning period. Fish sampling in the late summer was conducted to provide an inventory of species composition, abundance and relative biomass for the lake.

In both seasons, minnow trapping (using standard Gee minnow traps baited with dry cat food) was used in Kearl Lake as a sampling technique specific to the capture of forage fish and smaller life stages of large-bodied species in the littoral habitats that are present throughout the lake. For each sampling day, a total of 32 traps were set in four clusters (8 traps/cluster) and left to sample for a minimum of 4.3 hours per set. All minnow trapping effort was recorded per set as the number of traps set multiplied by the soak time to provide the number of trap-hours.

Gill netting was conducted in Kearl Lake to sample various habitats for large-bodied fish in both sampling seasons. Gill netting was conducted using one standardized multi-panel FWIN gill net left to sample for a minimum of 4.3 hours per set and checked at a minimum of every 2 to 3 hours to prevent fish mortality. Two daytime gill net sets were completed during each of the spring and late summer surveys. Gill net sampling effort was recorded for each net set as the number of hours of soak time to provide the number of net-hours.

Fish processing methods were the same as described for Muskeg Lake (Section 5.2.5.1), as were calculations of CPUE and BPUE.

5.3 Fish and Fish Habitat Results

The following sections provide a summary of the fish habitat and fish population data collected for the 2018 monitoring program for Muskeg Lake and Kearl Lake, as well as analytical data for samples collected in 2017 from Muskeg Lake that were not available for the 2017 Annual Monitoring Report.

Fish data collected in 2018 from Muskeg Lake (Station NNL-1) is part of the initial five-year annual monitoring program specified in the long-term SWFM Plan, with additional monitoring of the lake to be conducted at a frequency to be determined in consultation with DFO. The 2018 program marks the sixth year of monitoring the development of aquatic habitat and lower-level productivity (i.e., since filling of the lake in 2013), and the fifth year of monitoring fish colonization and population development (i.e., since Muskeg Lake was connected to Kearl Lake in 2014).

5.3.1 2018 Habitat Suitability Data

A summary of the continuous water temperature, pH, dissolved oxygen and conductivity data that were collected in Muskeg Lake (NNL-1) by the datasonde located in the pelagic zone is provided in Table 5-6, including minimum, maximum, and mean parameters recorded for the months the datasonde was deployed. The pelagic datasonde functioned throughout the deployment period (late May through late August), while the littoral logger malfunctioned shortly after deployment in Late May.

The full pelagic datasonde records are presented as plots of the continuous minimum, maximum and mean parameter levels for the period of record for temperature in °C (Figure 5-1), dissolved oxygen in mg/L (Figure 5-2), pH (Figure 5-3), and specific conductivity in µS/cm (Figure 5-4). Seasonal in-situ water quality profile data for Muskeg Lake is presented in Table 5-7.

Table 5-6: Summary of Continual Water Quality Parameter Data for Muskeg Lake, 2018

Parameter	Location	Monthly Water Quality Parameter Statistics											
		May 29 – May 31			June 1 – June 30			July 1 – July 31			August 1 – August 29		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Temperature [°C]	Pelagic	16.45	17.72	17.03	13.74	17.48	14.69	14.34	22.63	19.02	14.97	22.86	19.81
Dissolved Oxygen [mg/L]		8.74	9.03	8.88	6.45	9.47	8.26	4.93	9.57	8.23	7.78	9.19	8.39
pH		8.16	8.53	8.50	8.19	8.67	8.43	7.86	8.85	8.61	8.59	8.85	8.74
Specific Conductivity [µS/cm]		258	260	259	257	268	262	250	270	258	250	256	254

Note: Min. = minimum; Max. = maximum; °C = Degrees Celsius; mg/L = milligrams per litre; µS/cm = microsiemens per cm.

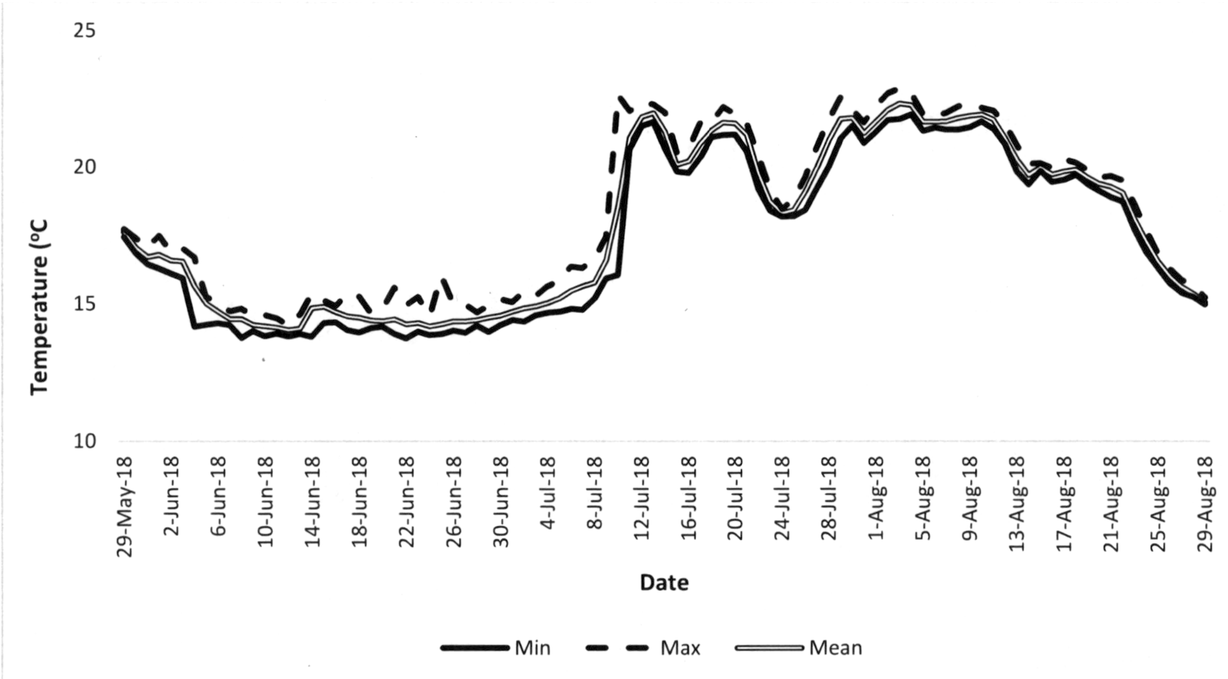


Figure 5-1: **Muskeg Lake Pelagic Zone Temperature Record, 2018**

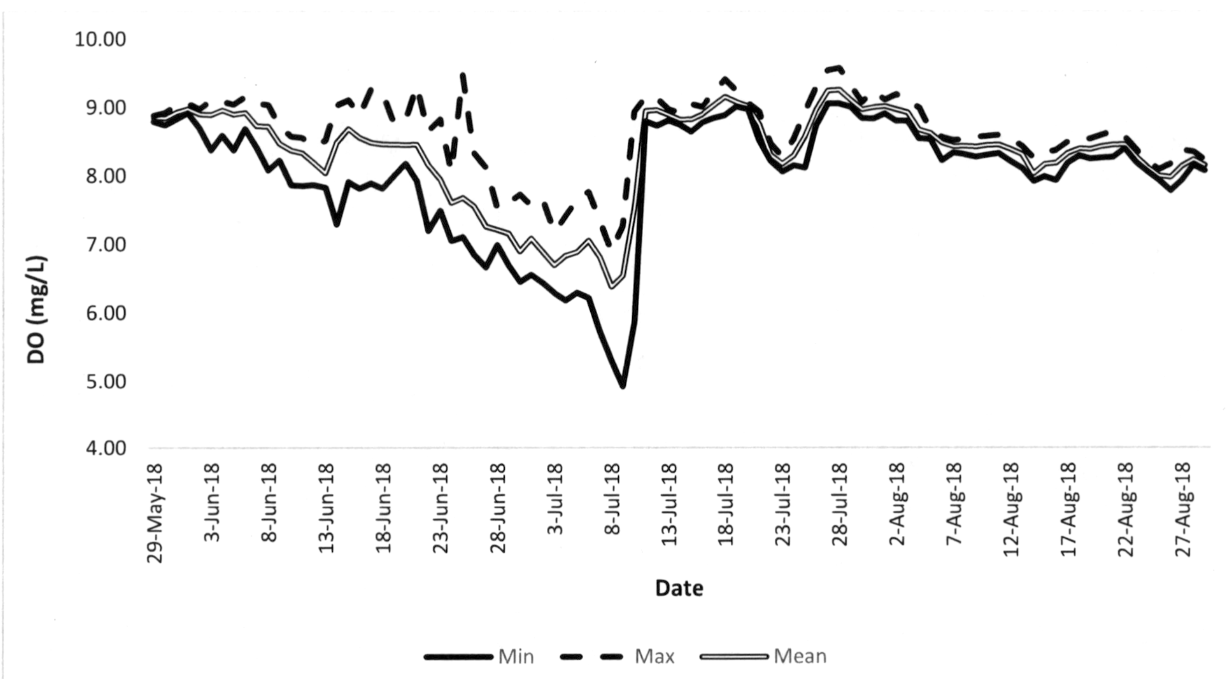


Figure 5-2: **Muskeg Lake Pelagic Zone Dissolved Oxygen Record, 2018**

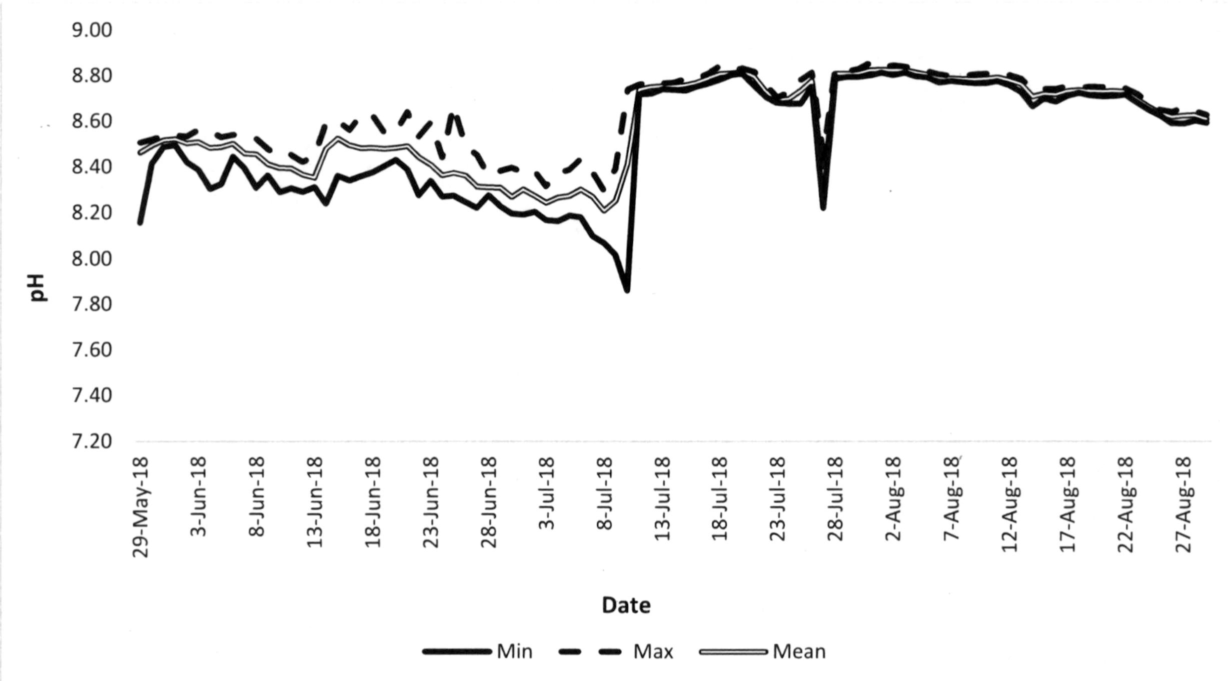


Figure 5-3: **Muskeg Lake Pelagic Zone pH Record, 2018**

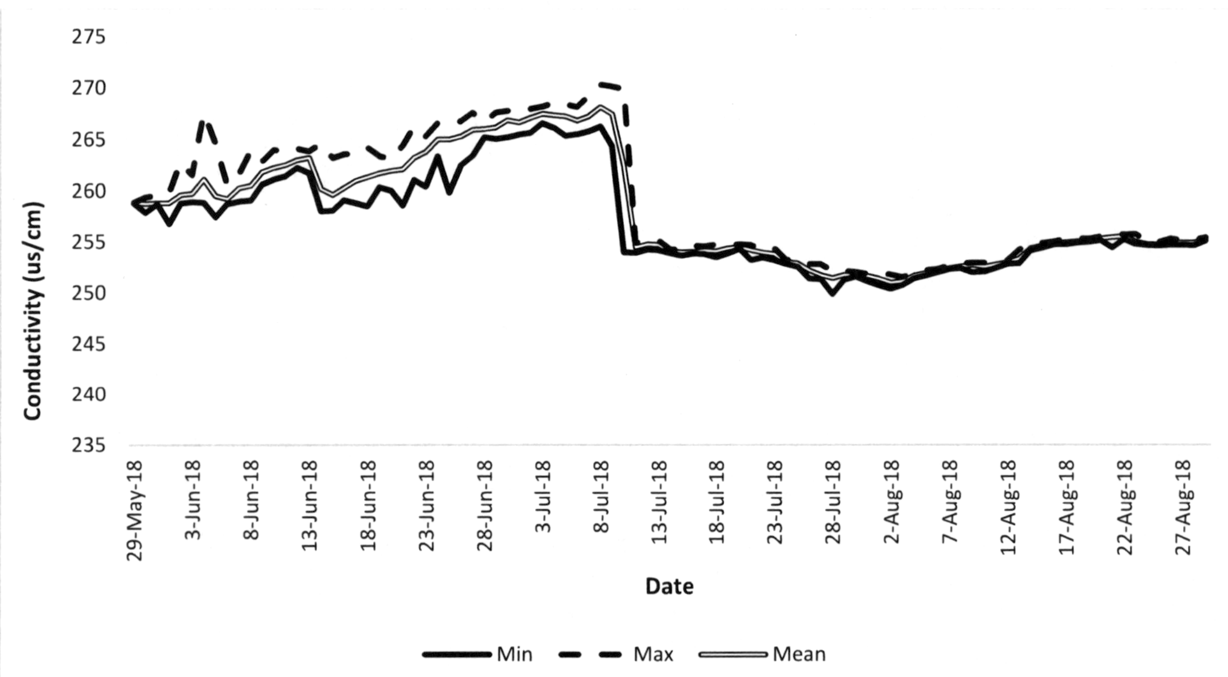


Figure 5-4: **Muskeg Lake Pelagic Zone Specific Conductivity Record, 2018**

Table 5-7: Seasonal In-Situ Water Quality Profile Data for Muskeg Lake, 2018

Station	Season	Water Quality Profile Location	Maximum Water Depth [m]	Profile				
				Depth [m]	pH	Conductivity [µS/cm]	Dissolved Oxygen [mg/L]	Temperature [°C]
NNL-1	Winter[(a)]	1	6.7	0.5	7.90	231	6.02	0.40
				1.0	7.70	208	5.80	0.91
				1.5	7.70	224	5.20	2.62
				2.0	7.60	261	4.76	3.80
				2.5	7.60	262	4.81	3.84
				3.0	7.60	261	4.80	2.96
				3.5	7.50	262	3.60	4.25
				4.0	7.50	262	3.68	4.10
				4.5	8.00	290	3.27	3.95
				5.0	8.00	290	3.43	3.91
				5.5	8.10	291	3.11	3.92
				6.0	8.10	292	2.80	3.88
				6.5	8.20	297	2.22	4.10
	Spring	1	6.2	0.3	8.37	274	8.15	16.11
				0.5	8.36	274	7.93	16.05
				1.0	8.34	274	7.98	16.06
				2.0	8.34	274	7.99	15.93
				3.0	8.32	274	8.11	15.86
				4.0	8.21	284	9.38	11.50
				5.0	7.96	291	8.61	8.51
				6.0	7.75	294	7.10	7.56
	Late Summer	1	6.3	0.3	8.09	253	10.18	11.00
				1.0	8.10	253	9.98	11.00
				2.0	8.11	253	9.76	11.00
				3.0	8.10	253	9.79	11.00
				4.0	8.11	253	9.69	11.00
				5.0	8.11	253	9.64	11.00
				6.0	8.11	253	9.70	10.90
		2	2	0.3	8.10	253	9.69	10.90
				0.5	8.10	253	9.79	10.90
				1.0	8.10	253	9.47	10.60
				1.5	8.10	253	9.45	10.30
		3	4.5	0.3	8.09	253	10.10	11.00
				0.5	8.09	253	9.80	11.00
				1.0	8.09	253	9.61	11.10
				1.5	8.10	253	9.68	11.00
				2.0	8.09	253	9.65	11.00
				2.5	8.09	253	9.59	11.00
				3.0	8.09	253	9.65	10.90
				3.5	8.09	253	9.83	10.90
				4.0	8.08	253	9.56	10.80
		4	4.7	0.3	8.09	253	10.17	10.90
				0.5	8.09	253	9.87	10.90
				1.0	8.10	253	9.82	10.90
				1.5	8.09	253	9.77	10.90
				2.0	8.10	253	9.64	10.90
				2.5	8.10	253	9.62	10.80
				3.0	8.10	253	9.71	10.80
				3.5	8.10	253	9.64	10.80
				4.0	8.10	253	9.65	10.80
				4.5	8.10	253	9.76	10.70

(a Data obtained from water quality winter survey.

Note: m = metres; µS/cm= microSiemens per centimetre; mg/L= milligrams per litre; °C = degrees Celsius.

5.3.2 2018 Aquatic Macrophyte Data

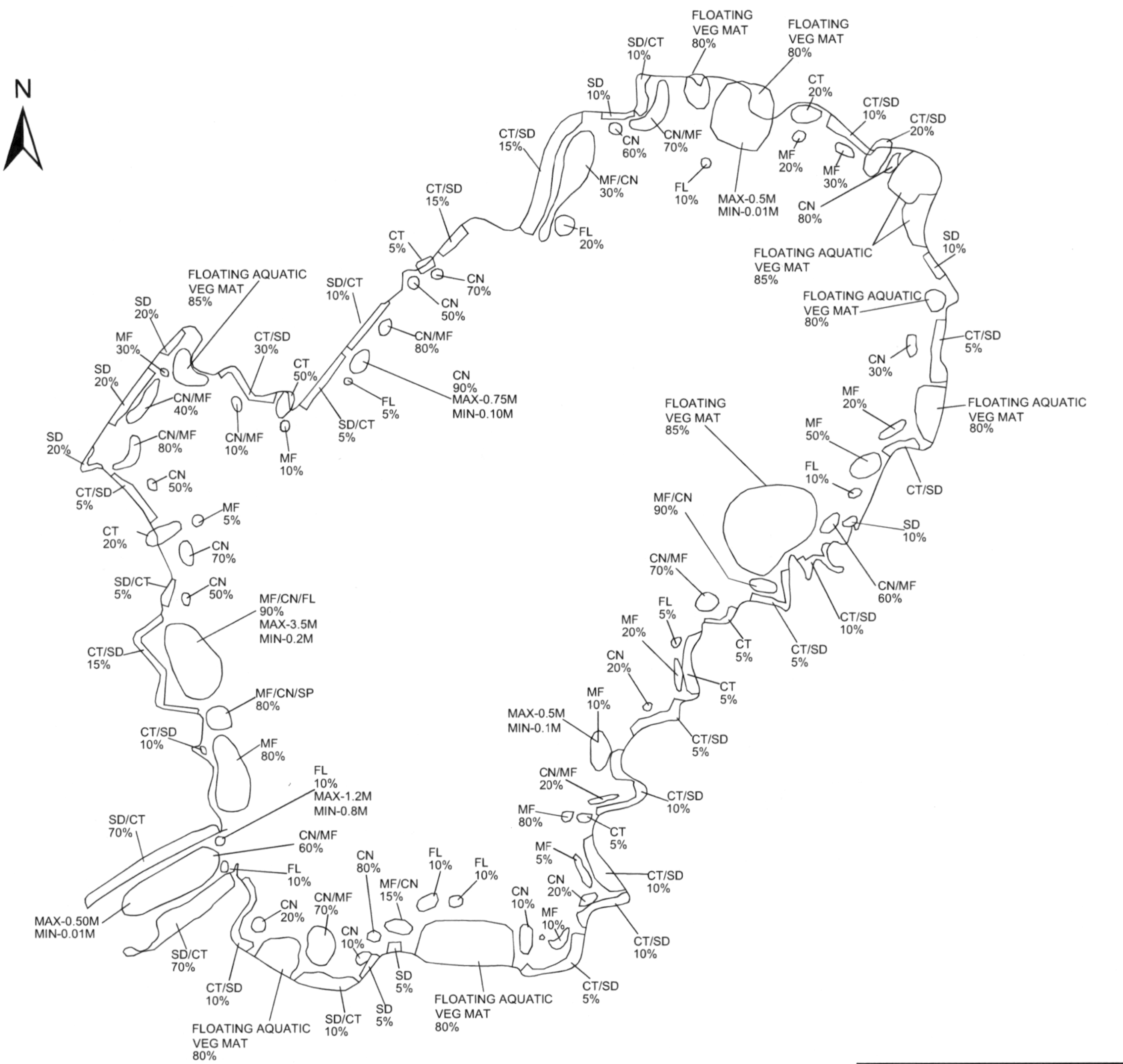
Aquatic macrophyte stands were planted in the littoral zone of Muskeg Lake following filling of the lake basin in 2013 (Golder 2013b) to initiate macrophyte establishment and supplement natural plant colonization. The planted stands were subsequently assessed in 2014 and 2015 for survival, vigor and evidence of expansion. The 2016, 2017 and 2018 Muskeg Lake monitoring programs included mapping the distribution and composition of aquatic macrophytes throughout the lake's entire littoral zone.

The 2018 map of aquatic macrophytes is presented in Figure 5-5 and identifies 100 areas of aquatic macrophytes in the Muskeg Lake littoral zone. The vegetation identified included Sedges (*Cyperaceae*), Cattail (*Typha*), Sago Pondweed (*Potamogeton pectinatus*), Floating Leaf Pondweed (*P. natans),* Coontail (*Ceratophyllum demersum*) and Northern Water Milfoil (*Myriophyllum exalbescens*). The presence of floating aquatic vegetation mats was also found throughout the lake. Figure 5-6, Figure 5-7 display pictures of the near-shore zone of Muskeg Lake. Figure 5-8 and Figure 5-9 display pictures of submergent and emergent vegetation found in Muskeg Lake.

074-0050-325-55 01

AutoCAD

CADD DRAWING NO MANUAL CHANGES



LEGEND

SD - SEDGE
SP - SAGO PONDWEED
CT - CATTAIL
CN - COONTAIL
MF - NORTHERN WATER MILFOIL
FL - FLOATING LEAF PONDWEED
% - PERCENT COVER FOR FISH
MAX - MAXIMUM STAND DEPTH
MIN - MINIMUM STAND DEPTH

Version: 3

A-PSTD

NOTES:
DRAWING CREATED FROM THE FIELD SKETCH.

Imperial

IMPERIAL OIL RESOURCES

KEARL - MINING
MUSKEG LAKE AQUATIC VEGETATION 2018
VEGETATION MAP

PROJECTION	DATUM	CONTRACTOR NAME	CONTRACTOR DRAWING NUMBER
UTM 12N	NAD83	GOLDER ASSOCIATES LTD.	FIGURE 5-5

DRAWN	CHECK	DESIGN	APPR.	DATE	SCALE	MAP NUMBER	REV
JF		AC		06 03 25	NOT TO SCALE	074-0050-325-55 01	A

Filename: L:\IMPERIAL_OIL\KEARLMINING\18110265\02_PRODUCTION\100\DWG\18110265_100-HS-0001.DWG User ID: BMCDONALD Plot date/time: March 25, 2019 - 9:27am



Figure 5-6: **Riparian and Littoral Zones of Muskeg Lake, August 2018**



Figure 5-7: **Riparian and Littoral Zones of Muskeg Lake, August 2018**



Figure 5-8: Littoral Submergent Vegetation in Muskeg Lake, August 2018



Figure 5-9: Floating Vegetation Mat in Muskeg Lake, August 2018

5.3.3 Plankton Data

5.3.3.1 2017 Plankton Results

Analytical results for plankton samples collected from Muskeg Lake during the 2017 monitoring survey that were not available at the time of preparation of the 2017 Annual Monitoring Report are presented here.

Taxonomic richness of phytoplankton and zooplankton in Muskeg Lake in 2017 are summarized in Table 5-8. Taxonomic richness refers to the number of different taxa recorded in the plankton samples. Taxonomic richness was calculated at the genus level for both phytoplankton and zooplankton, as this was the lowest taxonomic level recorded for all organisms in the samples collected. Immature forms for which genus was not determined were excluded from calculations of richness. Mean richness and richness range were calculated based on the individual results of the three composite samples collected from the lake. Total taxonomic richness is the total number of unique taxa recorded for all composite samples combined.

Table 5-8: Summary of Plankton Taxonomic Richness for Muskeg Lake, 2017

Variable	Zooplankton	Phytoplankton
Richness Range (No. taxa per sample)	11 to 15	32 to 38
Mean Richness (mean No. taxa) ± SE	13.0 ± 1.2	35.0 ± 1.7
Total Richness (total No. taxa)	16	59

Note: Calculations based on three composite samples collected at representative locations; No. = number; SE = standard error.

Total and relative percent zooplankton abundance and biomass recorded by major taxonomic group in Muskeg Lake in 2017 are presented in Table 5-9, and the dominant zooplankton taxa are presented in Table 5-10. Total and relative percent phytoplankton abundance and biomass of the major taxonomic groups recorded in Muskeg Lake in 2017 are presented in Table 5-11, and the dominant phytoplankton taxa are present in Table 5-12.

Table 5-9: Total and Percent Zooplankton Abundance and Biomass in Muskeg Lake, 2017

Taxonomic Group	Mean Abundance ± SE [organisms/m^3]	Relative Abundance [%]	Mean Biomass ± SE [µg/m^3]	Relative Biomass [%]
Rotifera	470,919 ± 88,150	98.03	225,549 ± 43,476	95.58
Cladocera	5,793 ± 352	1.21	5,411 ± 2,101	2.29
Cyclopoida	3,674 ± 2,115	0.76	4,810 ± 2,266	2.04
Calanoida	17 ± 17	< 0.01	219 ± 219	0.09
All Taxa	480,403 ± 89,226	100.00	235,989 ± 46,516	100.00

Note: Calculations based on average of three composite samples collected at representative locations; SE = standard error; µg = microgram; m^3 = cubic metre; < = less than.

Table 5-10: Dominant Zooplankton Taxa by Biomass in Muskeg Lake, 2017

Dominant Taxa[(a)] (Genus)	Mean Biomass [µg/m^3]	Relative Biomass [%]
Keratella	133,106	56.4
Polyathra	46,829	19.8
Pleurotrocha	32,163	13.6
Total	**212,098**	**89.8[(b)]**

(a) Dominant taxa are those comprising 4.0% or more of the total biomass.
(b) Percentage is less than 100% because species with a relative biomass of less than 4.0% were not included in the table.
Note: Calculations based on average of three composite samples collected at representative locations; µg = microgram; m^3 = cubic metre.

Table 5-11: Total and Percent Phytoplankton Abundance and Biomass in Muskeg Lake, 2017

Taxonomic Group	Mean Abundance ± SE [organisms/L]	Relative Abundance [%]	Mean Biomass ± SE [µg/m³]	Relative Biomass [%]
Cyanobacteria	4,503,820 ± 280,039	71.00	7,689,069 ± 764,471	89.40
Chrysophyceae	1,026,682 ± 173,073	16.17	217,748 ± 44,674	2.53
Cryptophyceae	338,445 ± 67,301	5.34	271,313 ± 78,075	3.15
Chlorophyceae	209,869 ± 44,301	3.31	57,604 ± 9,755	0.68
Diatoms	207,982 ± 42,109	3.28	96,670 ± 20,104	1.12
Dinophyceae	45,377 ± 6,549	0.72	186,391 ± 95,573	2.17
Euglenophyceae	11,344 ± 11,344	0.18	81,022 ± 81,022	0.95
All Taxa	6,343,519 ± 334,879	100.00	8,599,817 ± 834,633	100.00

Note: Calculations based on average of three composite samples collected at representative locations; SE = standard error; L = litre; µg = microgram; m³ = cubic metre

Table 5-12: Dominant Phytoplankton Taxa by Biomass in Muskeg Lake, 2017

Dominant Taxa[(a)] (Genus)	Mean Biomass [µg/m³]	Relative Biomass [%]
Planktothrix	7,063,262	82.1
Limnothrix	603,746	7.0
Total	**7,667,008**	**89.1**[(b)]

(a) Dominant taxa are those comprising 4.0% or more of the total biomass.
(b) Percentage is less than 100% because species with a relative biomass of less than 4. 0% were not included in the table.
Note: Calculations based on average of three composite samples collected at representative locations; µg = microgram; m³ = cubic meter

Comparison of 2017 plankton sampling results to previous years (2013 to 2016) for Muskeg Lake indicate the following patterns.

- Zooplankton mean abundance and biomass have steadily increased year-over-year – levels recorded in 2017 were the highest to date for Muskeg Lake (approximately a 16-fold increase in mean abundance and a nine-fold increase in biomass from 2016).
  - The large increase in Muskeg Lake zooplankton biomass and abundance recorded in 2017 can be attributed to increases in populations of Rotifer species (e.g., *Keratella* sp, *Polyathra* sp, and *Pleurotrocha* sp.) which represented 98% and 96% of the relative abundance and biomass, respectively.
  - Zooplankton taxonomic richness (total taxa) remained high relative to most previous monitoring years but was lower in 2017 than in 2016.
- Phytoplankton mean abundance and biomass has varied year-over-year but was generally similar between years from 2013 to 2016. Mean abundance and biomass recorded from Muskeg Lake in 2017 reached peak levels to date, showing a large increase from the previous years – in 2017, mean phytoplankton abundance increased by approximately two-fold and mean biomass increased by approximately six-fold from the previous year (2016).
  - The large increase in Muskeg Lake phytoplankton biomass and abundance can be attributed to a large population of one Cyanobacteria species (*Planktothrix agardhii*) which represented 49% and 82% of the relative abundance and biomass, respectively.
  - Phytoplankton taxonomic richness (total taxa) was at the high end of the range of values recorded in all monitoring years.

5.3.3.2 2018 Plankton Results

Taxonomic richness of phytoplankton and zooplankton in Muskeg Lake in 2018 are summarized in Table 5-13. Taxonomic richness refers to the number of different taxa recorded in the plankton samples. Taxonomic richness was calculated at the genus level for both phytoplankton and zooplankton, as this was the lowest taxonomic level recorded for all organisms in the samples collected. Immature forms for which genus was not determined were excluded from calculations of richness. Mean richness and richness range were calculated based on the individual results of the three composite samples collected from the lake. Total taxonomic richness is the total number of taxa recorded for all composite samples combined.

Table 5-13: Summary of Plankton Taxonomic Richness for Muskeg Lake, 2018

Variable	Zooplankton	Phytoplankton
Richness Range (No. taxa per sample)	15 to 17	34 to 40
Mean Richness (mean No. taxa) ± SE	16.0 ± 0.6	38.0 ± 1.8
Total Richness (total No. taxa)	20	65

Note: Calculations based on three composite samples collected at representative locations; No. = number; SE = standard error.

Total and relative percent zooplankton abundance and biomass of the major taxonomic groups recorded in Muskeg Lake in 2018 are presented in Table 5-14, and the dominant zooplankton taxa are presented in Table 5-15. Total and relative percent phytoplankton abundance and biomass of the major taxonomic groups recorded in Muskeg Lake in 2018 are presented in Table 5-16, and the dominant phytoplankton taxa are present in Table 5-17.

Table 5-14: Total and Percent Zooplankton Abundance and Biomass in Muskeg Lake, 2018

Taxonomic Group	Mean Abundance ± SE [organisms/m^3]	Relative Abundance [%]	Mean Biomass ± SE [µg/m^3]	Relative Biomass [%]
Rotifera	47,301 ± 4,222	67.81	54,615 ± 2,020	54.05
Cyclopoida	17,312 ± 842	24.82	44,146 ± 2,243	43.69
Cladocera	5,092 ± 813	7.30	1,919 ± 584	1.90
Calanoida	51 ± 15	0.07	367 ± 107	0.36
All Taxa	69,756 ± 5,087	100.00	101,047 ± 11,527	100.00

Note: Calculations based on average of three composite samples collected at representative locations; SE = standard error; µg = microgram; m^3 = cubic metre.

Table 5-15: Dominant Zooplankton Taxa by Biomass in Muskeg Lake, 2018

Dominant Taxa[(a)] (Genus)	Mean Biomass [µg/m^3]	Relative Biomass [%]
Asplanchna	29,198	47.4
Kellicotia	9,816	15.9
Keratella	6,261	10.2
Collotheca	3,875	6.3
Synchaeta	2,841	4.6
Total	**51,991**	**84.4[(b)]**

(a) Dominant taxa are those comprising 4.0% or more of the total biomass.
(b) Percentage is less than 100% because species with a relative biomass of less than 4.0% were not included in the table.
Note: Calculations based on average of three composite samples collected at representative locations; µg = microgram; m^3 = cubic metre.

Table 5-16: Total and Percent Phytoplankton Abundance and Biomass in Muskeg Lake, 2018

Taxonomic Group	Mean Abundance ± SE [organisms/L]	Relative Abundance [%]	Mean Biomass ± SE [µg/m³]	Relative Biomass [%]
Cyanobacteria	3,349,503 ± 523,170	65.94	2,331,185 ± 510,146	78.89
Chrysophyceae	720,377 ± 181,780	14.18	151,539 ± 44,569	5.13
Cryptophyceae	368,697 ± 108,221	7.26	89,672 ± 22,423	3.03
Chlorophyceae	365,854 ± 81,165	7.20	70,195 ± 11,733	2.38
Diatoms	235,397 ± 45,643	4.63	67,403 ± 18,375	2.28
Dinophyceae	28,360 ± 15,007	0.56	175,374 ± 90,872	5.94
Euglenophyceae	11,344 ± 5,672	0.22	69,498 ± 55,050	2.35
All Taxa	5,079,531 ± 902,070	100.00	2,954,867 ± 718,893	100.00

Note: Calculations based on average of three composite samples collected at representative locations; SE = standard error; L = litre; µg = microgram; m³ = cubic metre.

Table 5-17: Dominant Phytoplankton Taxa by Biomass in Muskeg Lake, 2018

Dominant Taxa[a] (Genus)	Mean Biomass [µg/m³]	Relative Biomass [%]
Limnothrix	1,517,026	51.3
Jaaginema	796,813	27.0
Total	**2,313,839**	**78.3[b]**

[a] Dominant taxa are those comprising 4.0% or more of the total biomass.
[b] Percentage is less than 100% because species with a relative biomass of less than 4.0% were not included in the table.
Note: Calculations based on average of three composite samples collected at representative locations; µg = microgram; m³ = cubic meter.

Comparison of 2018 plankton sampling results to previous years (2013 to 2017) for Muskeg Lake indicate the following patterns.

- Zooplankton mean abundance and biomass steadily increased year-over-year from 2013 until 2017. Mean abundance and biomass in 2018 decreased by seven-fold and two-fold, respectively, from the previous year (2017). Although 2018 mean abundance and biomass decreased from 2017 levels, they remained greater than levels recorded from 2013 to 2016.
  - Zooplankton taxonomic richness (total taxa) increased 23% from 2017, and was the highest level recorded to date.
- Phytoplankton mean abundance and biomass varied year-over-year from 2013 to 2016, followed by a large increase in 2017. Mean abundance and biomass in 2018 decreased by 20% and 66%, respectively, from the previous year (2017) but remained higher than the levels recorded prior to 2017.
  - Phytoplankton taxonomic richness (total taxa) reached peak levels in 2018 with an 8% increase in mean richness from the previous year (2017).

5.3.4 Benthic Invertebrate Data

5.3.4.1 2017 Benthic Invertebrate Results

Analytical results for the benthic invertebrate samples collected in 2017 that were not available at the time of preparation of the 2017 Annual Monitoring Report are presented here.

In the late summer of 2017, benthic invertebrate samples were collected from two locations in Muskeg Lake – littoral (shallow water) and pelagic (deep water). Littoral and pelagic samples were collected to test for differences in benthic invertebrate densities between these two key habitat categories and to check for overall benthic invertebrate diversity across a portion of the range of available habitats.

Categorization of mean total density of benthic invertebrates in 2017 (Table 5-18) was moderate (i.e., between 5,000 and 50,000 organisms/m^2) for both the littoral (14,433 organisms/m^2) and pelagic (6,797 organisms/m^2) sampling locations. Total taxonomic richness was moderate (i.e., between 10 and 40 taxa/site) at both the littoral (31 taxa) and pelagic (17 taxa) sampling locations. Diversity indices were high (i.e., >0.75) and evenness was moderate (i.e., between 0.25 and 0.75) at both the littoral and pelagic sampling locations. Moderate evenness indicates that although the benthic invertebrate communities at the sampling locations were diverse, the distribution of organisms was somewhat uneven among the taxa.

Table 5-18: Benthic Invertebrate Density, Richness, Diversity and Evenness in Muskeg Lake, 2017

Variable	Muskeg Lake (NNL-1)	
	Shallow (Littoral)	Deep (Pelagic)
Density (No./m^2)		
Mean Total Density	14,433	6,797
SE	±2,987.3	±1,073.6
Richness (No. of taxa)		
Mean Richness (No. taxa/sample)	19	13
SE	±2.1	±1.5
Total Richness (total No. of taxa)	31	17
Indices		
Simpson’s Diversity	0.86	0.78
Evenness	0.41	0.39

Note: Calculations based on three replicate samples; No. = number; m^2 = square metre; SE = standard error.

The relative abundance and density of common benthic invertebrate taxa at the littoral and pelagic sampling locations in Muskeg Lake in 2017 are presented in Table 5-19. Common benthic invertebrate taxa include those taxa that comprise 1% or more of the total number of organisms at any site. The benthic invertebrate community at the littoral sampling location was dominated by non-biting midges (Chironomidae family), seed shrimp (Ostracoda Class) and sandflies (Ceratopogonidae family), which comprised approximately 71%, 16% and 8% of the community, respectively. The benthic invertebrate community at the pelagic sampling site was dominated by non-biting midges (Chironomidae family) and seed shrimp (Ostracoda Class), which comprised approximately 60% and 32% of the community, respectively.

Table 5-19: Relative Abundance and Density for Common Benthic Invertebrate Taxa in Muskeg Lake, 2017

Taxonomic Group		Muskeg Lake (Littoral)				Muskeg Lake (Pelagic)			
Major Group (Order/Family)	Major Taxa (Family/Genus/Species)	Mean Abundance [No./sample]	Relative Abundance [%]	Mean Density [No./m^2]	±SE [No./m^2]	Mean Abundance [No./sample]	Relative Abundance [%]	Mean Density [No./m^2]	±SE [No./m^2]
Diptera / Chironomidae	*Parakiefferiella sp.*	77.7	23.4	3,377	1,481	-	-	-	-
	Tanytarsus sp.	42.4	12.8	1,842	757	15.7	10.0	681	361
	Cryptochironomus sp.	39.5	11.9	1,718	183	2.3	1.5	101	14
	Paratendipes sp.	20.1	6.1	874	426	-	-	-	-
	Endochironomus sp.	17.6	5.3	765	386	-	-	-	-
	Chironomini	16.0	4.8	694	327	-	-	-	-
	Cladotanytarsus sp.	13.5	4.1	586	87	-	-	-	-
	Cryptotendipes sp.	8.2	2.5	356	138	-	-	-	-
	Chironomus sp.	-	-	-	-	43.0	27.5	1,870	870
	Procladius sp.	-	-	-	-	17.3	11.1	754	95
	Cladopelma sp.	-	-	-	-	9.3	6.0	406	101
	Polypedilum halterale	-	-	-	-	2.7	1.7	116	38
	Tanypus sp.	-	-	-	-	1.7	1.1	72	52
	Polypedilum nubeculosum	-	-	-	-	2.0	1.3	87	43
Ostracoda (Class)	*Ostracoda*	54.0	16.3	2,347	565	50.7	32.4	2,203	591
Diptera / Ceratopogonidae	*Ceratopogoninae*	26.5	8.0	1,150	219	-	-	-	-
Tubificida / Naididae	*Naididae*	-	-	-	-	6.3	4.1	275	254
Diptera / Chaoboridae	*Chaoborus sp.*	-	-	-	-	2.0	1.3	87	50
	Total	**315.5**	**95.2[(a)]**	**13,709**	**4,569**	**153.0**	**98.0[(a)]**	**6,652**	**2,469**

(a) Percentage is less than 100% because species with a relative abundance of less than 1.0% were not included in the table.

Note: Calculations based on three replicate samples; No. = number; SE = standard error; - = not present or below 1 % relative abundance; m^2 = square metre.

Comparison of 2017 benthic invertebrate sampling results to previous data for Muskeg Lake (2013 to 2016) shows the following patterns.

- Littoral zone invertebrate communities have been steadily increasing since filling of the lake.
  - Invertebrate density has increased from zero in 2013 (littoral zone only recently inundated) to 14,433 org/m^2 in 2017 (fifth year since inundation), which is comparable to the density observed in 2016 (i.e., <1% difference).
  - Invertebrate taxonomic richness increased year-over-year from 2013 until 2016, however, richness decreased by 38% in 2017 from the previous year (2016).
- Pelagic zone invertebrate communities have changed as the lake was filled and the pelagic zone depth increased.
  - Pelagic invertebrate densities and richness showed a high degree of year to year variability during the earlier years of the monitoring program (i.e., 2013 to 2014), reflecting the period when water levels in the lake had been increasing as the lake was filled. With subsequent stabilization of water levels, benthic invertebrate density and richness in the pelagic zone was initially low (2014 to 2016) but showed a large increase in 2017.
  - Current pelagic density (6,797 org/m^2) and richness (17 total taxa) are lower than in the littoral zone, as expected for deep-water habitats.

5.3.4.2 2018 Benthic Invertebrate Results

In the late summer of 2018, benthic invertebrate samples were collected from two locations in Muskeg Lake – littoral (shallow water) and pelagic (deep water). Littoral and pelagic samples were collected to test for benthic differences in benthic invertebrate densities between these two key habitat categories and to check for overall benthic invertebrate diversity across a portion of the range of available habitats.

Categorization of mean total density of benthic invertebrates in 2018 (Table 5-20) was moderate (i.e., between 5,000 and 50,000 organisms/m^2) for the littoral sampling location (11,625 organisms/m^2) and low (i.e., <5,000 organisms/m^2) for the pelagic sampling location (3,281 organisms/m^2). Taxonomic richness was moderate (i.e., between 10 and 40 taxa/site) at both the littoral (31 total taxa) and pelagic (12 total taxa) sampling locations. The diversity index was high (i.e., >0.75) for the littoral zone samples (0.86) and moderate (i.e., between 0.25 and 0.75) for the pelagic samples (0.66). The evenness index was moderate (i.e., between 0.25 and 0.75) for both of the littoral (0.32) and pelagic (0.36) samples; moderate evenness indicates that although the benthic invertebrate communities at the sampling locations were diverse, the distribution of organisms was somewhat uneven among the taxa.

The relative abundance and density of common benthic invertebrate taxa at the littoral and pelagic sampling locations in Muskeg Lake in 2018 are presented in Table 5-21. Common benthic invertebrate taxa include those taxa that comprise 1% or more of the total number of organisms at any site. The benthic invertebrate community at the littoral sampling location was dominated by non-biting midges (Chironomidae family), a genus of mayfly (*Caenis* sp.), seed shrimp (Ostracoda family) and sandflies (Ceratopogonidae family), which comprised approximately 48%, 22%, 13% and 9% of the community, respectively. The benthic invertebrate community at the pelagic sampling site was dominated by non-biting midges (Chironomidae family) and seed shrimp (Ostracoda Class), which comprised approximately 70% and 19% of the community, respectively.

Table 5-20: Benthic Invertebrate Density, Richness, Diversity and Evenness in Muskeg Lake, 2018

Variable	Muskeg Lake (NNL-1)	
	Shallow (Littoral)	Deep (Pelagic)
Density (No./m²)		
Mean Total Density	11,625	3,281
SE	±1,285	±885
Richness (No. of taxa)		
Mean Richness (No. taxa/sample)	23	9
SE	±0.7	±0.7
Total Richness (total No. of taxa)	31	12
Indices		
Simpson's Diversity	0.86	0.66
Evenness	0.32	0.36

Note: Calculations based on three replicate samples; No. = number; m^2 = square metre; SE = standard error.

Table 5-21: Relative Abundance and Density for Common Benthic Invertebrate Taxa in Muskeg Lake, 2018

Taxonomic Group		Muskeg Lake (Littoral)				Muskeg Lake (Pelagic)			
Major Group (Order/Family)	Major Taxa (Family/Genus/Species)	Mean Abundance [No./sample]	Relative Abundance [%]	Mean Density [No./m^2]	±SE [No./m^2]	Mean Abundance [No./sample]	Relative Abundance [%]	Mean Density [No./m^2]	±SE [No./m^2]
Diptera / Chironomidae	*Cryptochironomus sp.*	29.2	10.9	1,272	249	-	-	-	-
	Endochironomus sp.	19.0	7.1	825	217	-	-	-	-
	Parakiefferiella sp.	16.8	6.3	731	337	-	-	-	-
	Pseudochironomus sp.	16.4	6.1	712	286	-	-	-	-
	Glyptotendipes sp.	15.0	5.6	650	310	-	-	-	-
	Chironomini	11.8	4.4	515	84	-	-	-	-
	Dicrotendipes fumidus	10.5	3.9	457	251	-	-	-	-
	Stictochironomus sp.	3.5	1.3	153	43	-	-	-	-
	Tanytarsus sp.	3.1	1.2	137	47	2.0	2.7	87	43
	Cladotanytarsus sp.	3.1	1.1	133	75	-	-	-	-
	Chironomus sp.	-	-	-	-	40.3	53.4	1,754	607
	Procladius sp.	-	-	-	-	10.7	14.1	464	203
Diptera / Ceratopogonidae	*Ceratopogoninae*	24.0	9.0	1,042	558	-	-	-	-
Diptera / Chaoboridae	*Chaoborus sp.*	-	-	-	-	1.0	1.3	43	43
Caenidae	*Caenis sp.*	59.0	22.0	2,563	1,109	-	-	-	-
Ostracoda (Class)	*Ostracoda*	33.6	12.6	1,459	617	14.0	18.6	609	223
Ephemeroptera	-	4.4	1.6	191	81	-	-	-	-
Tubificida	*Naididae*	3.2	1.2	141	51	1.1	1.5	49	9
	Ilyodrilus templetoni	-	-	-	-	3.7	4.9	159	95
	Total	**252.6**	**94.3[(a)]**	**10,981**	**4,315**	**72.8**	**96.5[(a)]**	**3,165**	**1,223**

(a) Percentage is less than 100% because species with a relative abundance of less than 1.0% were not included in the table.
Note: Calculations based on three replicate samples; No. = number; SE = standard error; - = not present or below 1 % relative abundance; m^2 = square meter

Comparison of available benthic invertebrate sampling results to previous data for Muskeg Lake (2013 to 2017) shows the following patterns.

- Littoral zone invertebrate communities steadily increased from filling of the lake in 2013 until 2016, with 2017 levels being similar to 2016 and 2018 levels being 19% lower than 2017.
  - Littoral invertebrate richness remained the same in 2018 as that in 2017 with 31 taxa present; peak richness was recorded in 2016 with 54 taxa.
- Pelagic zone invertebrate communities have changed as the lake was filled and the pelagic zone depth increased:
  - Pelagic invertebrate densities and richness showed a high degree of year to year variability during the earlier years of the monitoring program, but overall density levels were low – this was followed by a large increase in density in 2017.
  - Pelagic invertebrate density and richness in 2018 decreased from peak levels recorded in 2017 by 52% and 29%, respectively.
  - Current pelagic density and richness are lower than in the littoral zone, as expected for deep-water habitats.

5.3.5 2018 Fish Population Data

A total of eight fish species were captured during the 2018 monitoring program at Muskeg Lake (NNL-1), consisting of one sport fish species, two sucker species and five small-bodied forage fish species:

- Northern Pike (*Esox lucius*);
- Longnose Sucker (*Catostomus catostomus*);
- White Sucker (*Catostomus commersonii*);
- Brook Stickleback (*Culaea inconstans*);
- Fathead Minnow (*Pimephales promelas*);
- Finescale Dace (*Phoxinus neogaeus*);
- Northern Redbelly Dace (*Chrosomus eos*); and
- Pearl Dace (*Margariscus margarita*).

A summary of total fish catch is provided in Table 5-22, including the total numbers of fish captured by species during the spring and late summer surveys with all capture methods combined. Seasonal catch numbers show the number of fish captured in the spring survey (9,607) to be higher than in the late summer survey (6,953). This is due primarily to the large number of some forage fish species (i.e., Brook Stickleback and Fathead Minnow) captured in the spring versus the late summer. This pattern of seasonal fish abundance is discussed further in Section 5.4.

Table 5-22: Total Number of Fish Captured During Seasonal Surveys in Muskeg Lake, 2018

Season	Species Captured								
	Small-Bodied Fish					Large-Bodied Fish			
	Brook Stickleback	Fathead Minnow	Finescale Dace	Northern Redbelly Dace	Pearl Dace	Northern Pike	Longnose Sucker	White Sucker	Total
Spring	2,841	4,007	2,310	328	32	38	2	49	9,607
Summer	164	953	2,870	111	2,802	48	0	5	6,953
Total	3,005	4,960	5,180	439	2,834	86	2	54	16,560

Minnow trapping catch-per-unit-effort (CPUE) data are provided in Table 5-23 for each of the nine meso-habitat types sampled. In addition to the forage fish shown in Table 5-23, a single juvenile longnose sucker was also captured by minnow trapping in the spring survey, and a single juvenile white sucker was captured in the late summer survey. Similar to total fish numbers, the minnow trapping CPUE data shows a higher total catch rate in the spring (2.55 fish/trap-hr) than in the late summer (2.01 fish/trap-hr). Based on the CPUE results per species, the difference in catch rates between spring and late summer was due mainly to reduced late summer catch rates for Brook Stickleback, Fathead Minnow, and to a lesser extent Northern Redbelly Dace. Conversely, Finescale Dace and Pearl Dace CPUE increasing from spring to late summer. In the spring, when only shallow littoral meso-habitats were sampled, the highest catch rate for forage fish was recorded in the habitat with macrophyte cover (Meso-habitat B). In the late summer with the full range of meso-habitats sampled, the highest forage fish CPUE (7.77 fish/trap-hour) was recorded in shallow littoral habitat with gravel/cobble cover (Meso-habitat D), mainly due to high catch rates for Pearl Dace and Finescale Dace in this meso-habitat. The next highest CPUE rates were also in the shallow littoral zone, either with macrophyte cover (Meso-habitat B, 5.77 fish/trap-hour) or no cover (Meso-habitat A, 3.02 fish/trap-hour).

Table 5-24 provides the total CPUE for gill netting in Muskeg Lake, with Northern Pike, Longnose Sucker and White Sucker being captured – one Pearl Dace was also captured in the late summer survey. As the lake is currently dominated by forage fish species, most fish were captured by minnow trapping. Gill net sampling results reflect colonization and population growth for the large-bodied fish community in Muskeg Lake. Similar to total fish numbers (Table 5-22), the gill netting CPUE data (Table 5-24) shows a higher total catch rate in the spring (3.19 fish/net-hr) than in the late summer (1.51 fish/net-hr). Based on the CPUE results per species, the difference in catch rates from spring to late summer is due mainly to reduced catch rates for White Suckers in the late summer. For all three large-bodied species captured, the length frequency distribution (Appendix VIII) shows both juvenile and adult fish were present in Muskeg Lake.

Table 5-25 provides the CPUE results for boat electrofishing in Muskeg Lake, with Brook Stickleback, Fathead Minnow, Finescale Dace, Pearl Dace, Northern Pike and White Sucker being captured in the shallow littoral meso-habitats that could be effectively sampled with this technique. The highest catch rate was recorded in the habitat with macrophyte cover (Meso-Habitat B) with a total CPUE of 5.87 fish/100seconds, mainly due to the high catch rates for Pearl Dace.

The average fish weights for Muskeg Lake are provided in Table 5-26 for forage fish species and Table 5-27 for large-bodied fish species. A small number of captured large-bodied fish (4 Northern Pike and 3 White Sucker) escaped before they were weighed. The average weights allow the calculation of fish biomass. At present, biomass calculation consisted of biomass-per-unit-effort (BPUE) to allow comparison of relative biomass. BPUE was calculated by multiplying the species CPUE (number of fish captured per unit sampling effort) by the average weight of the species (g/fish) to provide the weight (g) of fish captured per unit sampling effort. Average condition factors were calculated for each species captured in Muskeg Lake (Table 5-28). BPUE and condition factor comparisons are provided in Section 5.4.

Appendix VIII provides length frequency histogram plots for forage fish species captured in sufficient numbers (i.e., 30 or more), and for all large-bodied fish species. Representative photographs from Muskeg Lake sampling are displayed in Appendix IX.

The results of the forage fish mark-recapture test conducted during the late summer minnow trapping survey are presented in Table 5-29. A total of 46 marked fish were recaptured, with meso-habitat B (Shallow littoral with aquatic macrophyte cover) and D (shallow littoral with gravel/cobble cover) having the highest recapture success, with 21 and 19 fish recaptured, respectively. Overall, the number of recaptured fish was low (zero recaptures for some species and meso-habitats) and is an indication that additional sampling effort would be needed to increase the effectiveness of mark-recapture as a population estimate method for Muskeg Lake, or that alternative methods should be investigated.

Table 5-23: Minnow Trapping Catch-Per-Unit-Effort by Meso-Habitat and Abundance in Muskeg Lake, 2018

Season	Meso-Habitat Type	Meso-Habitat Description	Effort (trap-hours)	Catch-per-unit Effort (Number/trap-hour)					
				Brook Stickleback	Fathead Minnow	Finescale Dace	Northern Redbelly Dace	Pearl Dace	TOTAL
Spring	B	Shallow Littoral (0 to 2 m deep); fine substrate; moderate to high density aquatic macrophyte cover	1,247	0.41	1.78	1.40	0.16	0.01	3.76
	A	Shallow Littoral (0 to 2 m deep); fine substrate; no cover	1,248	0.96	0.89	0.40	0.04	0.01	2.30
	C	Shallow Littoral (0 to 2 m deep); fine substrate; large woody debris cover	1,246	0.91	0.54	0.05	0.07	0.00	1.57
	TOTAL		**3,741**	**0.76**	**1.07**	**0.62**	**0.09**	**0.01**	**2.55**
Late Summer	D	Shallow Littoral (0 to 2 m deep); gravel/cobble substrate	376	0.04	0.53	2.93	0.15	4.12	7.77
	B	Shallow Littoral (0 to 2 m deep); fine substrate; moderate to high density aquatic macrophyte cover	379	0.10	0.22	3.34	0.07	2.04	5.77
	A	Shallow Littoral (0 to 2 m deep); fine substrate; no cover	406	0.06	1.35	0.97	0.03	0.61	3.02
	C	Shallow Littoral (0 to 2 m deep); fine substrate; large woody debris cover	377	0.11	0.06	0.21	0.04	0.01	0.43
	G	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; boulder garden cover	367	0.03	0.17	0.01	0.00	0.21	0.42
	F	Deep littoral to mid pelagic (>2 to 5 m deep); gravel/cobble substrate	365	0.05	0.02	0.06	0.00	0.13	0.26
	I	Deep pelagic (>5 to 7 m deep); fine substrate and no cover	368	0.01	0.04	0.00	0.00	0.14	0.19
	H	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; large woody debris cover	382	0.02	0.04	0.01	0.00	0.04	0.11
	E	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; no cover	375	0.01	0.00	0.00	0.00	0.00	0.01
	TOTAL		**3,395**	**0.05**	**0.28**	**0.84**	**0.03**	**0.81**	**2.01**

Table 5-24: Gill Netting Catch-Per-Unit-Effort in Muskeg Lake, 2018

Season	Effort			Northern Pike		Longnose Sucker		White Sucker		Pearl Dace		TOTAL	
	No. of Nets	Duration (hr)	Total Net-hr	No.	CPUE (No./net-hr)	No.	CPUE (No./net-hr)	No.	CPUE (No./net-hr)	No.	CPUE (No./net-hr)	No.	CPUE (No./net-hr)
Spring	1	7.58	27.58	38	1.38	1	0.04	49	1.78	0	0.00	88	3.19
	1	9.00											
	1	4.25											
	1	6.75											
Late Summer	1	7.92	32.43	45	1.39	0	0.00	3	0.09	1	0.03	49	1.51
	1	8.58											
	1	8.08											
	1	7.85											

Note: hr = hour; No. = number; CPUE = catch-per-unit-effort

Table 5-25: Boat Electrofishing Catch-Per-Unit-Effort by Meso-Habitat in Muskeg Lake, 2018

Season	Meso-Habitat Type	Effort (seconds)	Brook Stickleback		Fathead Minnow		Finescale Dace		Pearl Dace		Northern Pike		White Sucker		Total	
			No. Captured	CPUE	No. Captured	CPUE	No. Captured	CPUE	No. Captured	CPUE	No. Captured	CPUE	No. Captured	CPUE	No. Captured	CPUE
Late Summer	A	877	1	0.11	0	0.00	0	0.00	3	0.34	0	0.00	0	0.00	4	0.46
	B	835	3	0.36	1	0.12	7	0.84	34	4.07	3	0.36	1	0.12	49	5.87
	C	497	0	0.00	3	0.60	0	0.00	0	0.00	0	0.00	0	0.00	3	0.60

Note: A = Shallow littoral (0 to 2 m), no cover; B = Shallow littoral, moderate-high density aquatic macrophytes; C = Shallow littoral, LWD; CPUE = catch-per-unit-effort; No. = number

Table 5-26: Average Forage Fish Weight Calculations for Muskeg Lake, 2018

Season	Species														
	Brook Stickleback			Fathead Minnow			Finescale Dace			Northern Redbelly Dace			Pearl Dace		
	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]
Spring	2,841	3,714.9	1.31	4,007	9,963.5	2.49	2,310	3,952.8	1.71	328	507.7	1.55	32	119.4	3.73
Late Summer	164	214.5	1.31	953	2,000.2	2.10	2,870	5,279.8	1.84	111	133.2	1.20	2,802	8,245.4	2.94

Note: g = grams; No. = number

Table 5-27: Average Large-Bodied Fish Weight Calculations for Muskeg Lake, 2018

Season	Species								
	Northern Pike			Longnose Sucker			White Sucker		
	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]	No. Measured	Total Weight [g]	Average Weight [g]
Spring	36	70,725	1,964.6	2	503.7	251.9	46	30,577	664.7
Late Summer	46	83,675.3	1.819.0	0	0	0	5	1,683	336.6

Note: g = grams; No. = number

Table 5-28: Average Condition Factor for Fish Species in Muskeg Lake, 2018

Season	Brook Stickleback		Fathead Minnow		Finescale Dace		Pearl Dace		Northern Redbelly Dace		Northern Pike		Longnose Sucker		White Sucker	
	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor	Sample Size	Average Condition Factor
Spring	39	1.07	43	1.18	41	1.13	32	1.40	52	1.14	36	1.00	2	1.31	46	1.54
Late Summer	45	0.89	59	1.30	73	1.17	63	1.11	50	0.96	46	0.96	-	-	5	2.04

Table 5-29: Number of Marked Fish Recaptured by Meso-Habitat in Muskeg Lake, 2018

Season	Meso-Habitat Type	Meso-Habitat Description	Species					
			Brook Stickleback	Finescale Dace	Fathead Minnow	Northern Redbelly Dace	Pearl Dace	Total
Late Summer	A	Shallow Littoral (0 to 2 m deep); fine substrate; no cover	0	2	4	0	0	6
	B	Shallow Littoral (0 to 2 m deep); fine substrate; moderate to high density aquatic macrophyte cover	0	15	1	0	5	21
	C	Shallow Littoral (0 to 2 m deep); fine substrate; large woody debris cover	0	0	0	0	0	0
	D	Shallow Littoral (0 to 2 m deep); gravel/cobble substrate	0	11	1	0	7	19
	E	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; no cover	0	0	0	0	0	0
	F	Deep littoral to mid pelagic (>2 to 5 m deep); gravel/cobble substrate	0	0	0	0	0	0
	G	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; boulder garden cover	0	0	0	0	0	0
	H	Deep littoral to mid pelagic (>2 to 5 m deep); fine substrate; large woody debris cover	0	0	0	0	0	0
	I	Deep pelagic (>5 to 7 m deep); fine substrate and no cover	0	0	0	0	0	0
Total		**All**	**0**	**28**	**6**	**0**	**12**	**46**

A summary of the development of fish populations in Muskeg Lake to date is provided in Section 5.4.

5.4 Summary of Muskeg Lake Current Biological Development

Construction of the Muskeg Lake basin and its physical habitat features was completed in 2010, and filling of the lake basin with water pumped from Kearl Lake was completed in the spring of 2013. The connector channel between Muskeg Lake and Kearl Lake was opened in 2014, allowing fish passage between the two lakes. With respect to biological colonization and development, plankton and benthic invertebrate communities were able to begin colonization of Muskeg Lake as the basin was filling with water. Aquatic vegetation propagules were planted in the riparian and littoral areas of Muskeg Lake in 2013 to enhance the natural revegetation of the riparian zone and natural colonization by aquatic plants from Kearl Lake. Fish populations were able to begin colonization of Muskeg Lake once the connector channel was opened in 2014.

This section provides a summary of the current level of development and trends for the biological components of the Muskeg Lake ecosystem that are included in the monitoring program, which involved integration of the following data.

- Assessments of the success of 2013 aquatic macrophyte plantings in 2014 to 2015, and littoral vegetation mapping from 2016 to 2018.
- Plankton sampling results from 2013 to 2018 (end of lake filling to present).
- Benthic invertebrate sampling results from 2013 to 2018 (end of lake filling to present).
- Fish population sampling results from 2014 to 2018 (connector channel opening to present).

The summary results were compared to Kearl Lake to provide an indication of the level of development of Muskeg Lake in comparison to a mature, natural lake that is also the main source for biological colonization. Further to this comparison, the summary results were compared to other waterbodies found in the region, where suitable data is available. The reasoning behind including regional lake comparisons is to see how Muskeg Lake compares to other lakes that also provide pelagic (deep-water) overwintering habitat for fish, which is limited in Kearl Lake.

5.4.1 Aquatic Macrophytes

Aquatic macrophyte stands were planted in the littoral zone of Muskeg Lake in August 2013, consisting of 25 stands of Richardson's Pondweed (*Potamogeton richardsonii*) propagules and 10 stands of Softstem Bulrush (*Schoenoplectus tabernaemontani*) propagules. Thirteen of the pondweed stands were planted in near-shore littoral areas (≤ 0.5 m deep) and twelve were planted in deeper littoral areas (>0.5 to 1.5 m deep). Bulrush stands were planted along the lake shoreline. The stands were assessed in 2014 and 2015 for percent survival, vigor and evidence of expansion. Success of the planted pondweed stands was observed to be low to moderate for the shallow plantings and nil for the deeper plantings. For pondweed stands planted in the shallow littoral zone, vigor was low to moderate, survival was moderate, and percent of rooted plants was low to moderate. Bulrush plantings were completely successful, with stands planted along the shoreline showing moderate to high vigor, high survival, and evidence of spreading.

In addition to the macrophyte plantings, natural colonization of the Muskeg Lake littoral zone has occurred for other emergent and submergent vegetation species, including Sedges (*Cyperaceae*), Cattail (*Typha*), Sago Pondweed (*Potamogedon pectinatus*), Floating Leaf Pondweed (*P. natans*), Northern Watermilfoil (*Myriophyllum exalbescens*), Coontail (*Ceratophyllum demersum*), White Water Buttercup (*Ranunculus longirostris*) and Muskgrass (*Chara*).

Mapping of aquatic vegetation in Muskeg Lake from 2016 to 2018 indicates continuing colonization and expansion of aquatic macrophytes in the lake. The 2018 map of aquatic macrophytes presented in Figure 5-5 identifies 100 areas of aquatic macrophytes in the littoral zone compared to 61 areas of aquatic macrophytes recorded in 2017 and 39 areas of aquatic macrophytes in 2016 (Golder 2017b). Further expansion of macrophyte distribution and density in Muskeg Lake is expected to continue through both new colonization and expansion of existing stands.

5.4.2 Plankton Communities

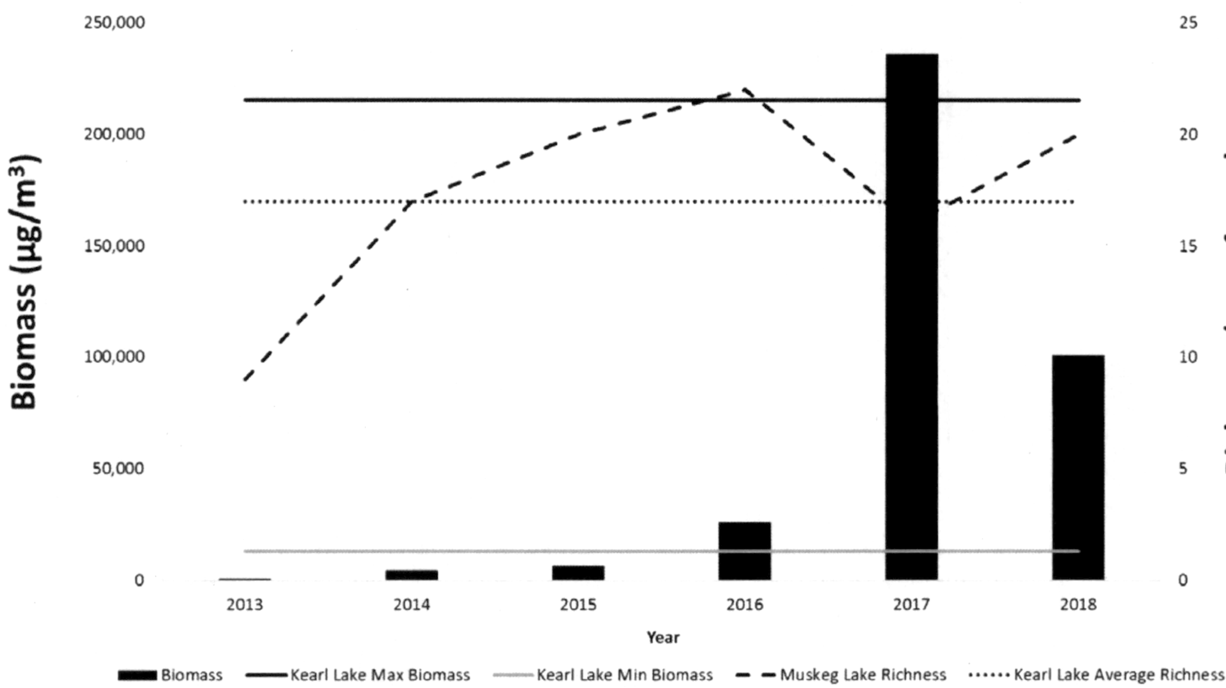
Plankton samples (zooplankton and phytoplankton) have been collected in Muskeg Lake to provide an indication of lake productivity. Plankton data is also available from Kearl Lake sampling that was conducted for the long-term SWFM program in 2009, 2010, 2012 and 2013, and allows comparison of plankton productivity in the newly developed Muskeg Lake to a natural lake with an established ecosystem. Both lakes are hydrologically connected allowing species from Kearl Lake to colonize Muskeg Lake. This section summarizes the yearly plankton biomass and taxonomic richness data from Muskeg Lake in comparison to the range of values for these parameters recorded in Kearl Lake.

5.4.2.1 Zooplankton Biomass and Taxonomic Richness

Zooplankton biomass and taxonomic richness increased consistently, but slowly, for the first four years following filling of Muskeg Lake (2013 to 2016), becoming variable in the most recent years (2016 to 2018) (Figure 5-10). The development of zooplankton biomass in Muskeg Lake required four years to achieve a level similar to the lower range of biomass recorded in Kearl Lake. This was followed by a large (nine-fold) increase in biomass in 2017, when Muskeg Lake levels were higher than the maximum level recorded in Kearl Lake. In 2018, Muskeg Lake biomass level declined relative to 2017, but was higher than all previous years, and was similar to the mid-range of biomass levels in Kearl Lake. Overall, zooplankton biomass in Muskeg Lake has either been within or above the observed range of Kearl Lake since 2016. The increase in zooplankton biomass in 2017 was due to the large population of Rotiers present that year. Rotifers feed on small phytoplankton (e.g., cyanobacteria; Wetzel 2001), therefore, the increase in phytoplankton biomass recorded in 2017 likely provided large amounts of food for zooplankton, enabling the increase in population size.

Zooplankton taxonomic richness in Muskeg Lake was initially below the average richness observed in Kearl Lake but has been similar to or higher than average levels in Kearl Lake since 2014 (Figure 5-10). Peak taxonomic richness in Muskeg Lake was observed in 2016 with 22 taxa.

These results indicate that zooplankton development in Muskeg Lake took two years (richness) to four years (biomass) to reach levels comparable to Kearl Lake. From four to six years after filling (2016 to 2018), zooplankton biomass and richness levels have been comparable to, or higher than, Kearl Lake. Based on the trend shown in Figure 5-10, Muskeg Lake zooplankton is expected to remain comparable to Kearl Lake in the future.



Note: Max = Maximum; Min = Minimum; µg = microgram; m^3 = cubic metre; no. = number

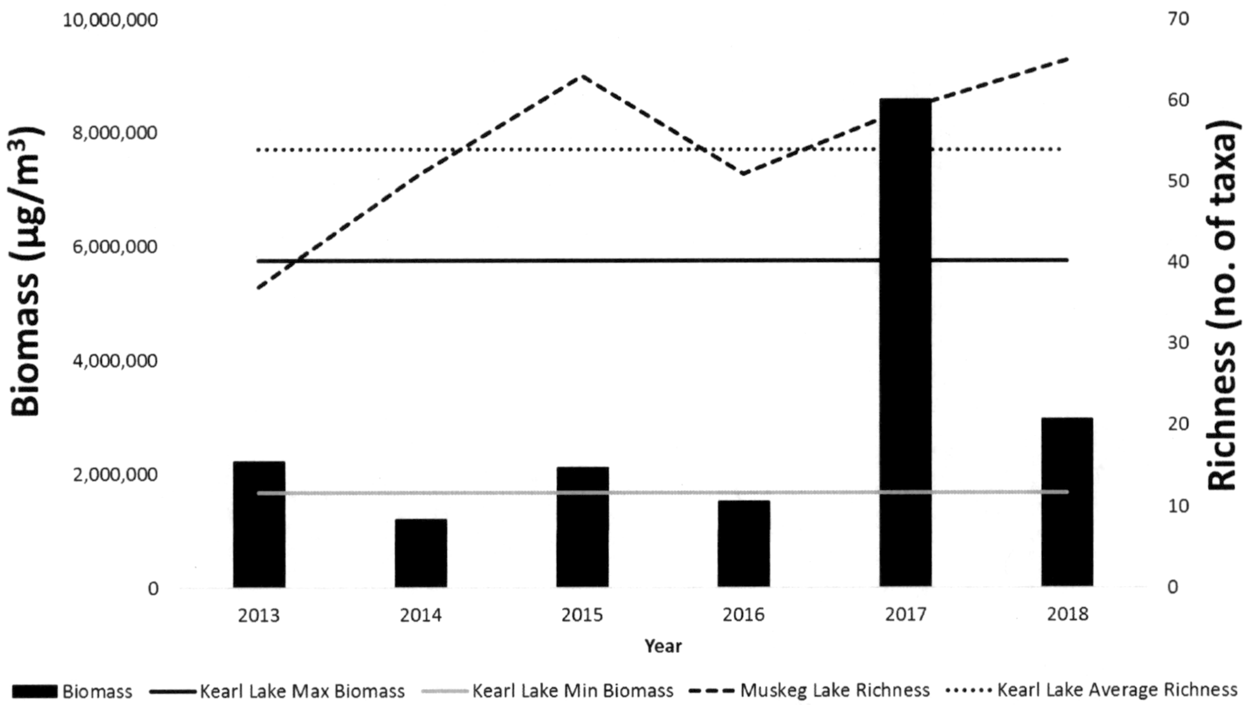
Figure 5-10: Summary of Zooplankton Biomass and Richness in Muskeg Lake, 2013 to 2018.

5.4.2.2 Phytoplankton Biomass and Taxonomic Richness

The development of Muskeg Lake phytoplankton biomass and taxonomic richness shows a different pattern than that of zooplankton. Rather than starting at a low level with a steady increase over the initial years of lake development, phytoplankton biomass and richness developed rapidly, followed by variable levels from year to year (Figure 5-11). By completion of lake filling in 2013, phytoplankton biomass and richness had already achieved levels similar to the lower range of values in Kearl Lake. From 2013 to 2016, biomass varied near the lower end of the Kearl Lake range until 2017, when biomass in Muskeg Lake showed a large increase and exceeded the upper range observed in Kearl Lake. Phytoplankton biomass in Muskeg Lake decreased in 2018 relative to the 2017 peak, but still remained within the range observed in Kearl Lake.

Phytoplankton taxonomic richness in Muskeg lake achieved the average richness observed in Kearl Lake by 2014 and has been similar to, or higher than, the Kearl Lake average since then.

The results indicate that phytoplankton development in Muskeg Lake was rapid, occurring during the lake filling phase from 2010 to 2013. For five of the six post-fill monitoring years (2013 to 2016 and 2018), phytoplankton biomass has been similar to the lower range observed in Kearl Lake, while 2017 levels exceeded the maximum Kearl Lake level. Results from the most recent two-year period (2017 and 2018) show consecutive year-to-year consistency in which phytoplankton biomass in Muskeg Lake has remained above the low range observed in Kearl Lake. Additional monitoring data will determine if phytoplankton production will continue to remain in, or exceed, ranges observed in Kearl Lake.



Note: Max = Maximum; Min = Minimum; µg = microgram; m^3 = cubic metre; no. = number

Figure 5-11: Summary of Phytoplankton Biomass and Richness in Muskeg Lake, 2013 to 2018.

5.4.3 Benthic Invertebrate Communities

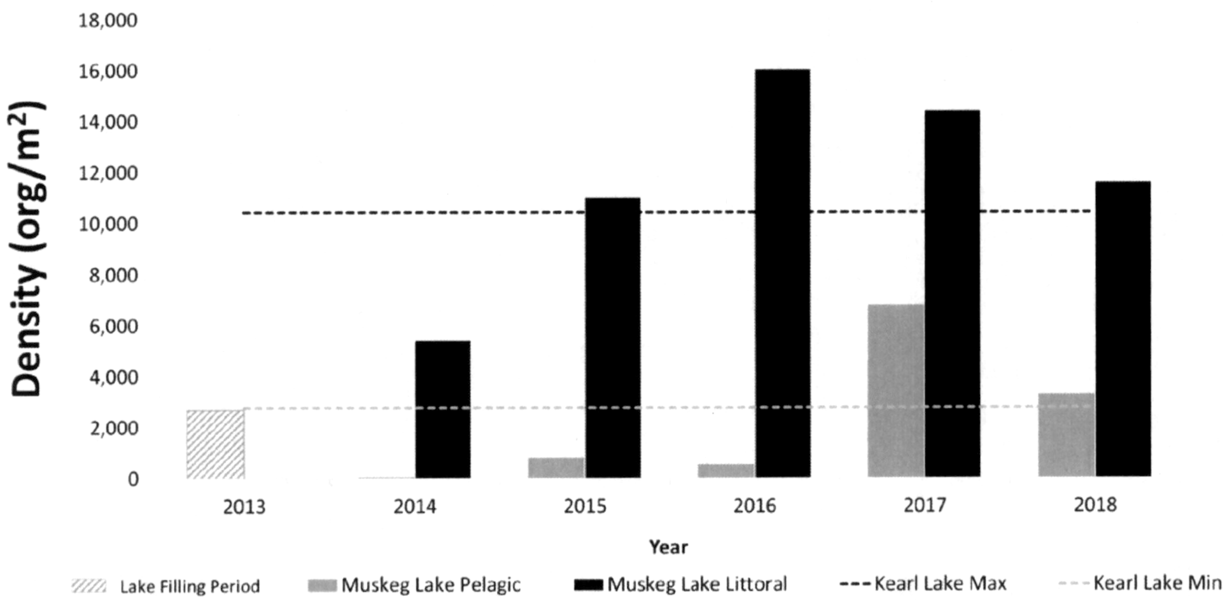
Benthic invertebrate data were collected in Muskeg Lake from 2013 to 2018 to provide an indication of lake productivity and development of the food base for non-piscivorous fish. Benthic invertebrate data is also available for Kearl Lake from sampling that was conducted by RAM from 2009 to 2013 and allows comparison of benthic invertebrate productivity in the newly developed Muskeg Lake to a natural lake with an established ecosystem that is also a primary source for invertebrate colonization. This section summarizes the yearly benthic invertebrate density and taxonomic richness data from Muskeg Lake in comparison to the same parameters provided for Kearl Lake by RAM. Kearl Lake data was limited to samples collected from the littoral zone of the lake, due to the lake's lack of pelagic habitat, while Muskeg Lake data has been collected from both the littoral and pelagic zones, as identified in the analysis.

The benthic invertebrate sampling results to date for Muskeg Lake show that density (Figure 5-12) and taxonomic richness (Figure 5-13) developed rapidly in the littoral zone following lake filling. In comparison, development was slower and more limited in the deep-water pelagic zone where density and richness levels were lower. Sampling after lake filling in 2013 showed density levels in Muskeg Lake were already similar to the lower range found in Kearl Lake, although richness was low at that time. The littoral benthic invertebrate data show that both density (Figure 5-12) and taxonomic richness (Figure 5-13) were either within the range or higher than the maximum levels recorded in Kearl Lake from the time of first sampling in 2014 onward. Peak density in Muskeg Lake occurring in 2016 (16,043 organisms per square meter). Benthic invertebrate densities in Muskeg Lake pelagic habitat remained below the Kearl Lake littoral range until 2017 and 2018, although this is not a direct comparison due to differences in habitat type (i.e., pelagic versus littoral).

Benthic invertebrate taxonomic richness within the littoral zone of Muskeg Lake has been within or above the range observed in Kearl Lake of 21 to 42 taxa from 2014 until present (2018) (Figure 5-13), with peak richness recorded in 2016 (50 taxa). Pelagic richness in Muskeg Lake has increased over time but remains below the range observed in the Kearl Lake littoral zone, with peak levels occurring in 2017 (17 taxa). Muskeg Lake total taxonomic richness for littoral and pelagic areas combined in 2016 (52 unique) exceeded the maximum range observed in Kearl Lake.

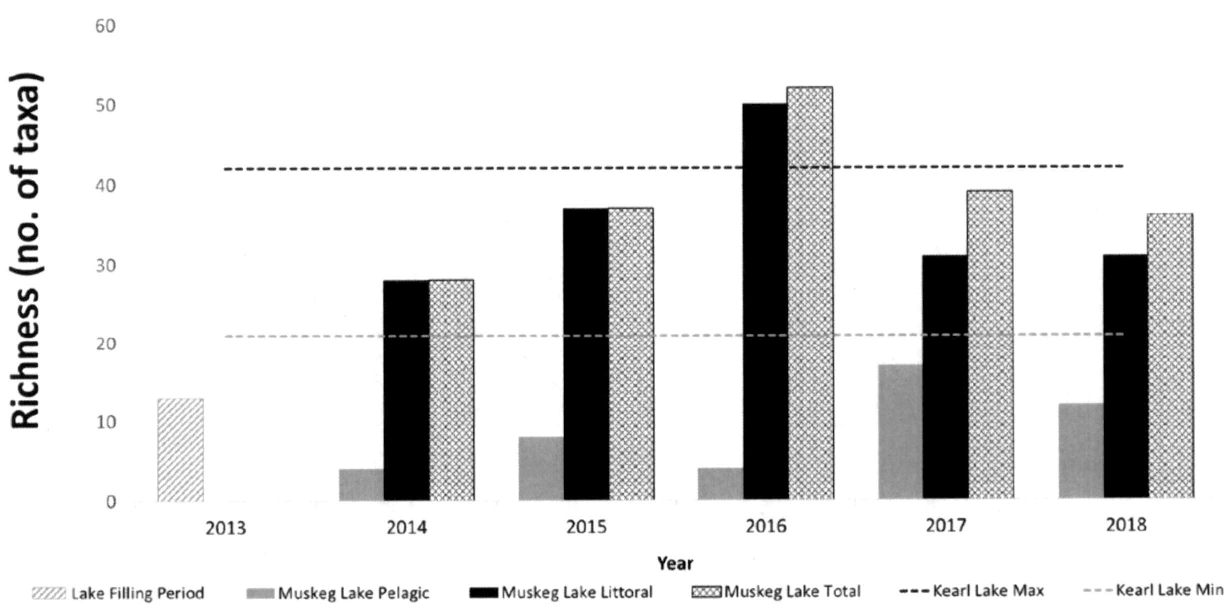
Overall, these results indicate that Muskeg Lake benthic invertebrate colonization began during the Muskeg Lake filling phase, followed by rapid colonization and development of the benthic invertebrate community in the littoral zone and slower development in the pelagic zone. In comparison to Kearl Lake, littoral benthic invertebrate density and richness levels in Muskeg Lake were similar to or exceeded levels typical of the natural lake within two years of filling, providing a strong food base for fish. The higher benthic invertebrate densities and richness levels in the Muskeg Lake littoral zone relative to the pelagic zone can be characterized as typical, as littoral habitats and associated macrophytes are known to provide zones of high biodiversity and productivity for macroinvertebrates (James et al. 1998). This suggests that the Muskeg Lake pelagic zone achieving density levels similar to the Kearl Lake littoral zone by 2017 (Figure 5-12) is another indication of good invertebrate productivity in Muskeg Lake.

The heterogeneous habitat in Muskeg Lake (e.g., combination of littoral and pelagic habitats) is likely contributing to the observable high richness versus that of Kearl Lake, due to greater habitat diversity. This point is illustrated by the 2018 Muskeg Lake pelagic samples, which contained several different taxa compared to that of the littoral samples (Table 5-21), adding to the overall richness of Muskeg Lake. In addition, the secure overwintering habitat in Muskeg Lake relative to the low winter dissolved oxygen levels that occur in Kearl Lake can be expected to support a higher density and diversity of invertebrates. Following the initial period of rapid development, benthic invertebrate density and richness in Muskeg lake appears to be stabilizing, exhibiting year-to-year variability at a relatively high level compared to Kearl Lake.



Note: Max = Maximum; Min = Minimum; org = organism; m^2 = square metre

Figure 5-12: Summary of Benthic Invertebrate Density in Muskeg Lake, 2013 to 2018



Note: Max = Maximum; Min = Minimum; no. = number

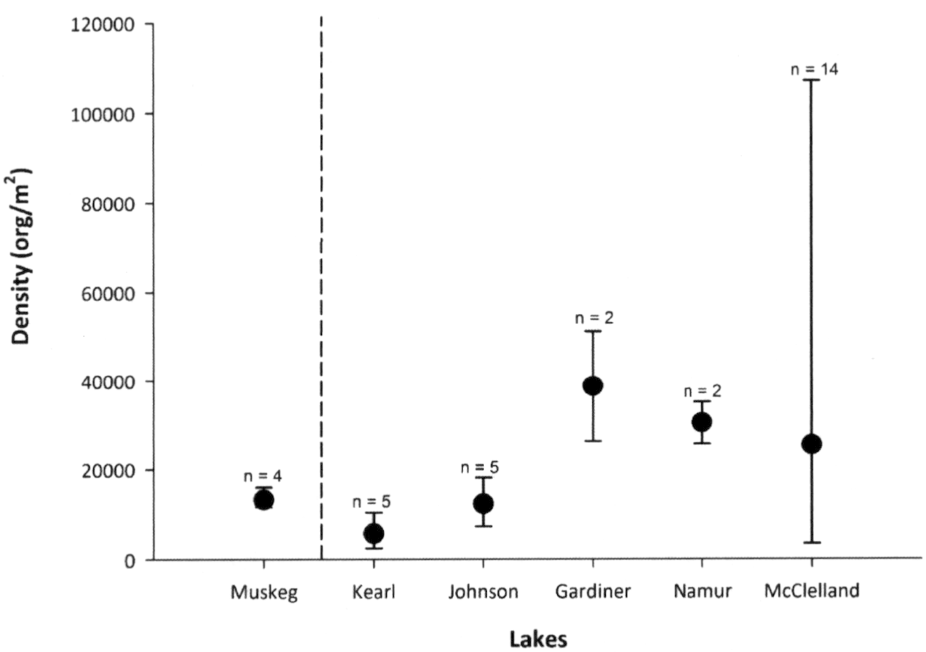
Figure 5-13: Summary of Benthic Invertebrate Richness in Muskeg Lake, 2013 to 2018

5.4.3.1 Regional Waterbody Comparison

Benthic invertebrate data have been collected in the littoral area of regional lakes by RAM sampling (AEMERA 2016). A total of four of these regional lakes (Namur, Gardiner, McClelland and Johnson lakes) were selected for comparison to Muskeg Lake, as they all occur within an approximate 90 km radius of Muskeg Lake and were sampled from 2002 to 2015. Post-colonization benthic invertebrate data for Muskeg Lake (i.e., 2015 to 2018) were used to represent current conditions compared to the regional lakes. Kearl Lake was also included in the comparison relative to the data presented in Section 5.4.3. The average benthic invertebrate density (with minimum/maximum range) (Figure 5-14) and average richness (with minimum/maximum range) (Figure 5-15) from each of the regional lakes were compared to Muskeg Lake.

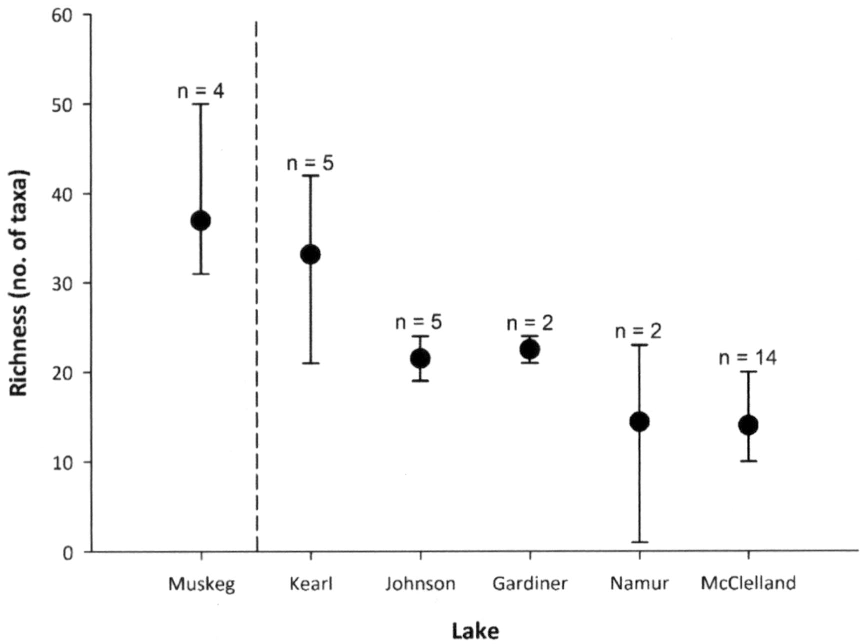
Similar to Muskeg lake, all lakes used in the comparison generally had benthic invertebrate densities classified as moderate (i.e., 5,000 to 50,000 organisms/m^2), with high densities (i.e., > 50,000 organisms/m^2) recorded on one occasion in McClelland Lake. The average benthic invertebrate densities within the littoral habitat of Muskeg Lake were most comparable to, and somewhat higher than, the smaller regional lakes (i.e., Kearl and Johnson lakes), but were lower than the average densities of the three larger regional lakes (Numar, Gardiner and McClelland lakes) (Figure 5-14), although average invertebrate densities at Muskeg Lake did fall within the range of McClelland Lake. Overall, invertebrate densities within the post-colonization phase of Muskeg Lake are comparable to some neighboring regional lakes but are lower than the larger regional lakes.

Benthic invertebrate taxonomic richness within the littoral habitat of Muskeg Lake was greater than the average richness recorded for all the regional lakes (Namur, Gardiner, McClelland and Johnson lakes) and most similar to its source lake (Kearl Lake) (Figure 5-15). Average richness in Muskeg Lake is at least 49% greater than the other regional lakes. These results suggest Muskeg Lake has a diverse range of littoral habitat selection for different groups of invertebrates relative to neighboring lakes.



Note: Regional lakes appear on x-axis according to size (smallest to largest - left to right); n = number of years sampled; org = organism; m^2 = square metre

Figure 5-14: Average Littoral Benthic Invertebrate Densities (± min/max) of Muskeg Lake in comparison to Regional Lakes.



Note: Regional lakes appear on x-axis according to size (smallest to largest - left to right); n = number of years sampled; no. = number

Figure 5-15: Average Littoral Benthic Invertebrate Richness (± min/max) of Muskeg Lake in Comparison to Regional Lakes.

5.4.4 Fish Populations

Fish population sampling has been conducted in Muskeg Lake to monitor the development of the various fish populations constituting the fish community. A comparison of fish capture results for Muskeg Lake to date (2014 to 2018) was conducted for fish community colonization, development and productivity trends, including species composition, average conditions factors, average fish weights, abundance (CPUE) and relative biomass (BPUE). Fish population data is also available from Kearl Lake sampling that was conducted for the long-term monitoring program from 2009 to 2013 and allows comparison of population parameters in the newly developed Muskeg Lake to a natural lake with an established ecosystem. Both lakes are connected physically, allowing species from Kearl Lake to colonize Muskeg Lake. This section summarizes the yearly fish population data from Muskeg Lake in comparison to Kearl Lake.

5.4.4.1 Species Composition

The number of fish species captured in Muskeg Lake has increased from five species in 2014 to a total of nine species captured for all years combined (Table 5-30). Species captured in Muskeg Lake to date include one sport fish species (Northern Pike), two sucker species (Longnose and White Sucker), and six forage fish species (Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Northern Redbelly Dace and Pearl Dace). The first species to colonize Muskeg Lake from Kearl Lake consisted of the some of the most common species in Kearl Lake, including white sucker and four forage fish species (Brook Stickleback, Finescale Dace, Lake Chub and Pearl Dace). Longnose Sucker and Fathead Minnow colonized Muskeg Lake in 2015, while Northern Pike and Northern Redbelly Dace were first captured in Muskeg Lake in 2016. With the exception of Northern Pike, all of the species captured in Muskeg Lake were documented to be present in Kearl Lake during the 2009 to 2013 monitoring program – Northern Pike were documented to be occasionally present in Kearl Lake in the historical record. All fish species documented to be present in Kearl Lake, either historically or during the monitoring program, have colonized Muskeg Lake.

Table 5-30: Muskeg Lake Fish Species Composition, 2014 to 2018

Species	Spring[(a)]				Summer					Total				
	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Brook Stickleback	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Finescale Dace	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fathead Minnow	X	X	X	X	-	X	X	X	X	-	X	X	X	X
Lake Chub	X	X	-	-	X	X	X	X	-	X	X	X	X	-
Northern Redbelly Dace	-	X	X	X	-	-	-	X	X	-	-	X	X	X
Pearl Dace	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Longnose Sucker	X	-	X	X	-	-	-	X	-	-	X	-	X	X
White Sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern Pike	-	X	X		-	-	X	X	X	-	-	X	X	X
Number of Species	7	8	8	8	5	6	7	9	7	5	7	8	9	8

(a) No fish sampling occurred in Spring 2014.

Note: X = species captured; - = species not captured.

5.4.4.2 Fish Size

Fish size for the species present in Muskeg Lake was examined by length frequency analysis (Appendix VIII), and by calculating average condition factor and average weights per species. Condition factor for species in Muskeg Lake compared to Kearl Lake are summarized in Table 5-31. Muskeg Lake average condition factors ranged from 0.92 to 1.70 across species, similar to that of Kearl Lake which ranged from 0.91 to 1.40. Individually, condition factors for some species in Muskeg Lake were slightly lower compared to Kearl Lake, while for other species they were slightly higher. The average weights for each small-bodied and large-bodied fish species are summarized in Tables 5-32 and 5-33, respectively. Overall, four out of the six forage fish species were, on average, heavier in Muskeg Lake than Kearl Lake. Average weights for sucker species were higher in Muskeg Lake than Kearl Lake, but the sample sizes are relatively small. Average Northern Pike size cannot be compared to Kearl Lake, where this species was not captured during the monitoring program.

Table 5-31: Average Fish Condition Factors, Muskeg Lake and Kearl Lake

Species	Condition Factor	
	Muskeg Lake (2014 - 2018)	Kearl Lake (2009 - 2013)
Brook Stickleback	0.96	1.19
Finescale Dace	1.13	1.40
Fathead Minnow	1.56	1.31
Lake Chub	1.13	1.23
Longnose Sucker	1.70	1.28
Northern Pike	0.92	Not present
Northern Red Belly Dace	1.06	0.91
Pearl Dace	1.15	1.25
White Sucker	1.61	1.36

Table 5-32: Average Forage Fish Weight Comparison, Muskeg Lake and Kearl Lake

Species	Weight (g)	
	Muskeg Lake (2014 - 2018)	Kearl Lake (2009 - 2013)
Brook Stickleback	1.2	1.8
Finescale Dace	1.6	1.4
Fathead Minnow	2.8	2.1
Lake Chub	1.9	1.7
Northern Red Belly Dace	1.7	1.1
Pearl Dace	3.6	8.8

Note: g = gram

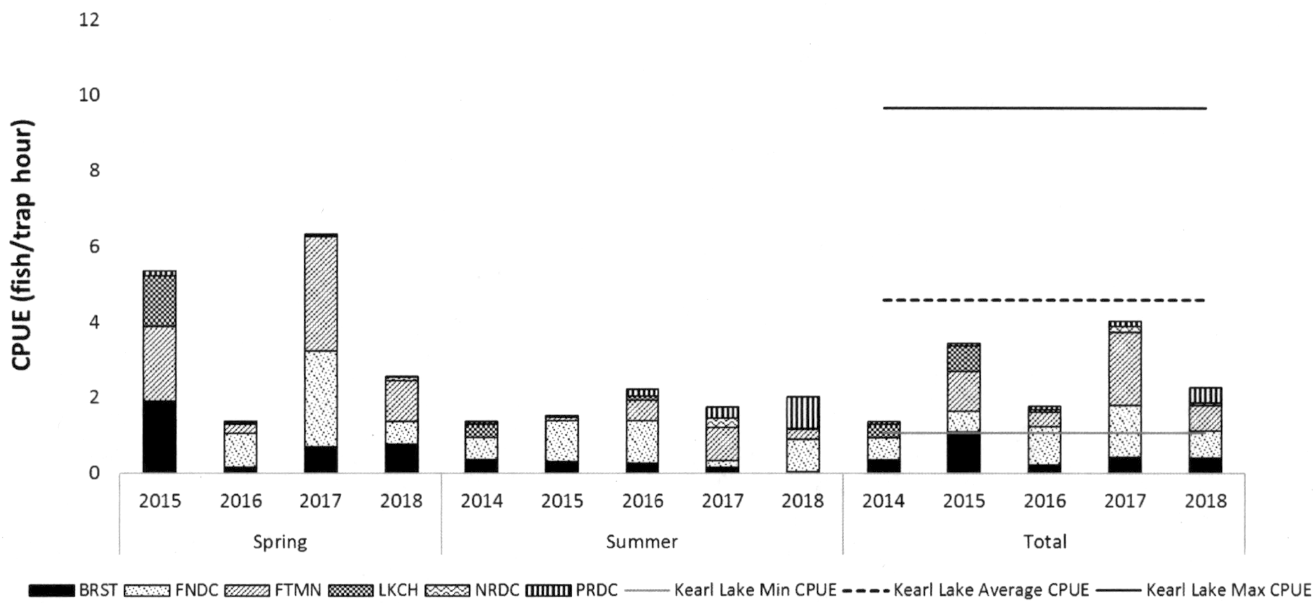
Table 5-33: Average Large-Bodied Fish Weight Comparison, Muskeg Lake and Kearl Lake

Species	Weight (g)					
	Muskeg Lake (2014 - 2018)			Kearl Lake (2009 - 2013)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Longnose Sucker	399.3	2.6	780.0	372.2	198.5	540.0
White Sucker	661.9	2.2	1,620.0	376.2	242.8	511.9
Northern Pike	1,909.3	75.3	5,440.0	Not present		

Note: g = gram

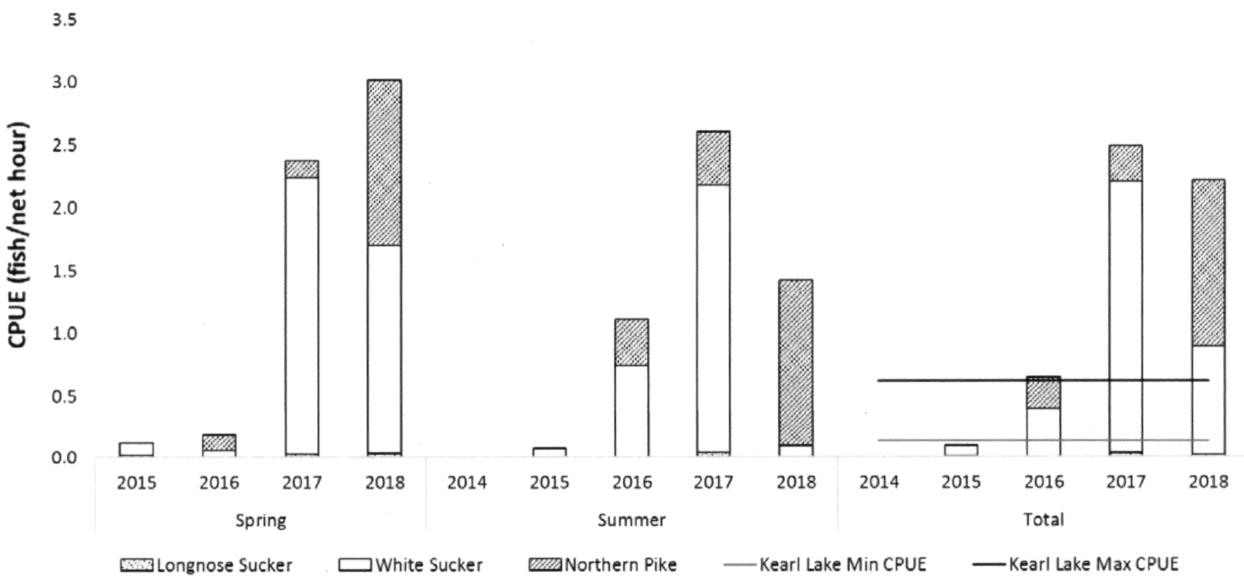
5.4.4.3 Fish Abundance and Relative Biomass

Fish abundance was determined by calculating Catch-per-unit-effort (CPUE). CPUE for minnow trapping (Figure 5-16) and gill netting (Figure 5-17) in Muskeg Lake from 2014 to 2018 are presented and compared to Kearl Lake baseline conditions. Kearl Lake maximum, average and minimum range lines for the total CPUE have been included in order to allow for visual comparison to Muskeg Lake total CPUE.



Note: CPUE = Catch-per-unit-effort; BRST = Brook Stickleback; FNDC = Finescale Dace; FTMN = Fathead Minnow; LKCH = Lake Chub; NRDC = Northern Redbelly Dace; PRDC = Pearl Dace; Max = maximum; Min = minimum

Figure 5-16: Summary of Total CPUE for Minnow Trapping in Muskeg Lake, 2014 to 2018

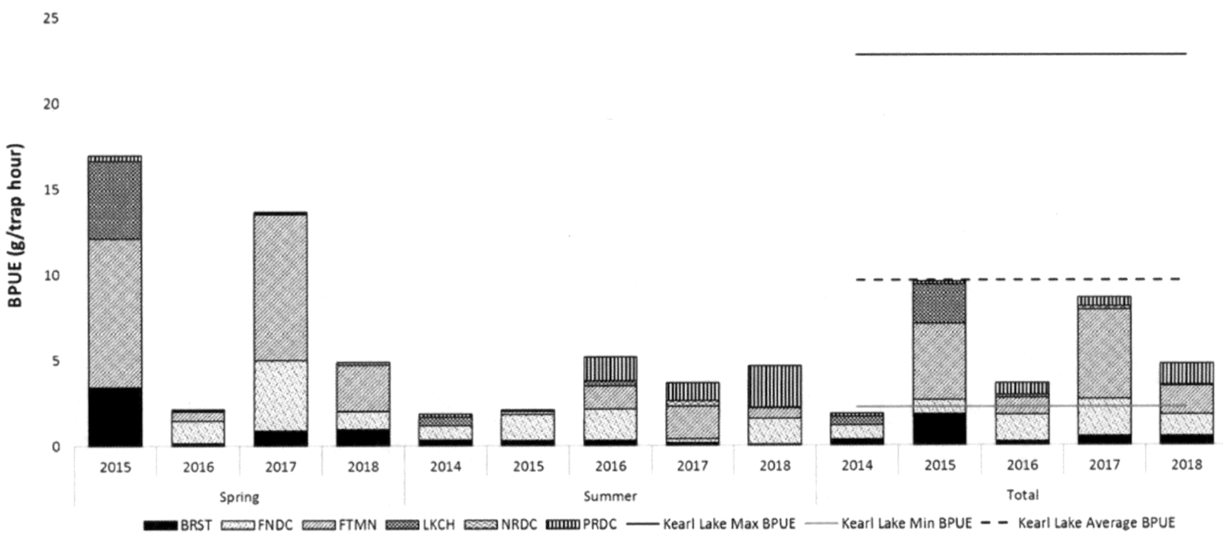


Note: CPUE = Catch-per-unit-effort; Max = maximum; Min = minimum

Figure 5-17: Summary of Total CPUE for Gill Netting in Muskeg Lake, 2014 to 2018

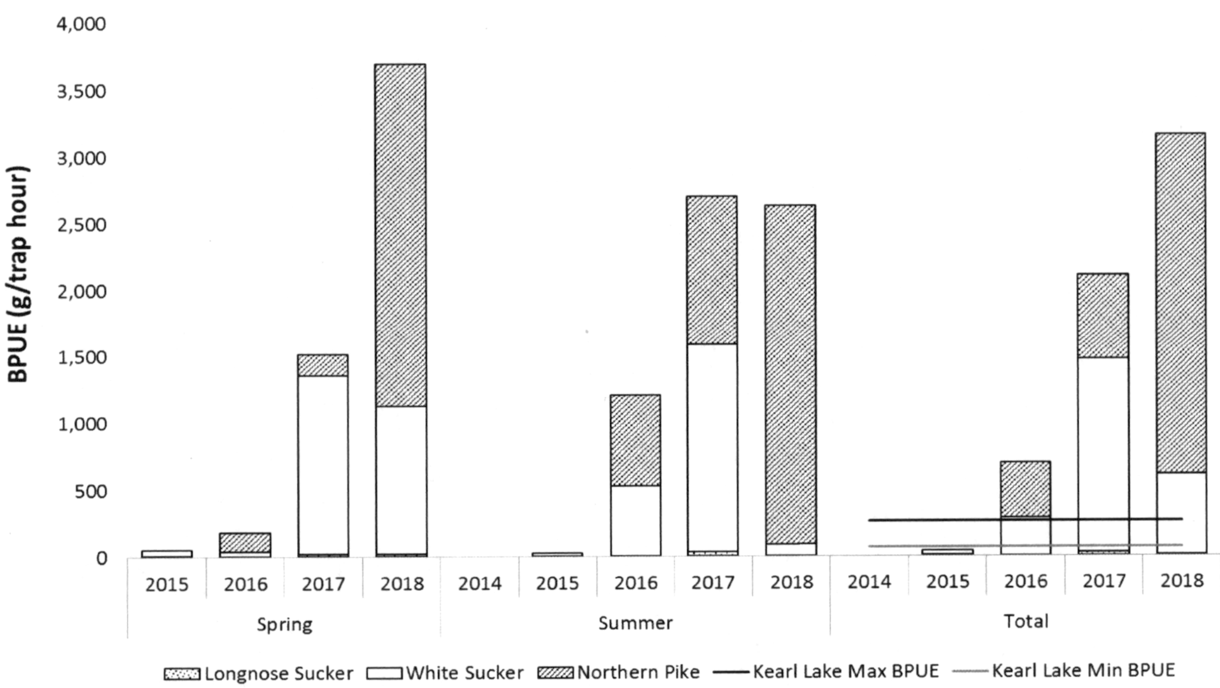
The results for total forage fish CPUE (all forage fish species and seasons combined) for Muskeg Lake were within the range of Kearl Lake from the summer of 2014 (the year the connector channel was opened) onwards (Figure 5-16). CPUE for large-bodied fish in Muskeg Lake approached the lower limit for Kearl Lake in 2015 and exceeded the upper limit from 2016 onwards (Figure 5-17).

In addition to CPUE, relative biomass (BPUE) is examined to provide a relation between fish abundance and productivity as it pertains to biomass production. Temporal trends in Muskeg Lake BPUE from 2014 to 2018 have been graphed for the minnow trap (Figure 5-18) and gill net (Figure 5-19) data. Kearl Lake maximum, average and minimum range lines for total BPUE have been included in order to allow comparison of Muskeg Lake relative biomass to that of Kearl Lake.



Note: BPUE = Biomass-per-unit-effort; g = gram; BRST = Brook Stickleback; FNDC = Finescale Dace; FTMN = Fathead Minnow; LKCH = Lake Chub; NRDC = Northern Redbelly Dace; PRDC = Pearl Dace; g = gram; Max = maximum; Min = minimum

Figure 5-18: Summary of Relative Biomass for Minnow Trapping in Muskeg Lake, 2014 to 2018



Note: BPUE = Biomass-per-unit-effort; g = gram: KEL = Kearl Lake; Max = maximum; Min = minimum

Figure 5-19: Summary of Relative Biomass for Gill Netting in Muskeg Lake, 2014 to 2018

Similar to the CPUE data, the results for total minnow trapping BPUE (all species and seasons combined) show rapid development of initial forage fish productivity by 2014 (the year the connector channel was opened), with BPUE levels approaching the lower range of the baseline levels recorded in Kearl Lake (Figure 5-18). This initial biomass development was followed by a large increase in total BPUE in 2015 and 2017. Although total forage fish BPUE appears to have been lower in 2016, this is likely explained by the seasonal variability in the BPUE data evident in Figures 5-16 and 5-18 in relation to the delayed spring sampling period that occurred in 2016. The CPUE and BPUE data shows that the high total values recorded in 2015 and 2017 are due to high values during the spring surveys, which were completed in late May in both years. The high BPUE values in the spring are due to the large fish catch recorded in late May. In comparison, the 2016 spring program was delayed until later in June because of the wildfire that affected the Fort McMurray area in May 2016. From Figures 5-16 and 5-18 it is evident that, in some years, Muskeg Lake was used by a large number of forage fish in the spring that are not present in the lake in the summer. This is likely due to some forage fish using Muskeg Lake in the winter for its secure overwintering habitat, then migrating to Kearl Lake for the summer. Based on the timing of the various spring surveys, it appears this migration took place in early June. Therefore, it is considered possible that total fish biomass in Muskeg Lake in 2016 may have been more similar to 2015 and 2017. In comparison, the total BPUE for forage fish in 2018, when spring sampling was again conducted in late May, was lower than 2015 and 2017, although it was within the range of Kearl Lake. This dip in BPUE could be associated with the increasing abundance of large-bodied fish (Figure 5-17), specifically Northern Pike - with the presence of this predatory species in Muskeg Lake it is possible that inter-specific interactions may be affecting the forage fish community.

Another consideration for comparison of forage fish abundance and biomass between Muskeg Lake and Kearl Lake is that Kearl Lake is composed entirely of one meso-habitat type (shallow littoral with dense vegetation) such that the total CPUE and BPUE values are based on one highly suitable habitat type. Conversely, Muskeg Lake sampling effort was evenly distributed among the nine available meso-habitat types, including many expected to provide low suitability for forage fish, such as habitats with no cover and deep-water habitats. Thus, the total CPUE/BPUE for Muskeg Lake can be expected to be lower than Kearl Lake. For example, comparing the CPUE for the meso-habitats found to be most suitable in Muskeg Lake in 2018 (shallow littoral with dense vegetation and shallow littoral with rocky substrate) shows that fish abundance in these two habitats ranges from 5.77 to 7.76 (Table 5-23), which are above the average CPUE values for Kearl Lake.

Based on the gill netting CPUE results (Figure 5-17) and BPUE results (Figure 5-19), the large-bodied fish species in Muskeg Lake have shown steadily increasing values with increased colonization by Northern Pike and suckers. Seasonal and total BPUE values exceeded levels in Kearl Lake by the third year following opening of the connector channel (i.e., summer of 2016) and onward, primarily due to expansion of Northern Pike and White Sucker populations. The 2018 results in particular showed a large increase in CPUE/BPUE for Northern Pike. White Sucker BPUE decreased somewhat in 2018, largely due to the lower catch rate of White Sucker in the late summer survey.

Overall, the CPUE and BPUE data indicates that Muskeg Lake, as planned, is providing secure overwintering habitat for both Muskeg Lake and Kearl Lake fish populations, as well as year-round habitat for forage fish, suckers and sport fish. The CPUE/BPUE trends for Muskeg Lake indicate that the forage fish community developed rapidly and reached abundance levels within the range of Kearl Lake levels almost immediately (i.e., the same year the connector channel to Kearl Lake was opened), and BPUE levels were within the range of Kearl Lake the year following the channel opening. Starting in the second year of fish access, forage fish BPUE in Muskeg Lake has been within the range of that recorded in Kearl Lake, varying from the low to mid range. It should be noted that Kearl Lake has a high variability in CPUE/BPUE for forage fish, attributed to the highly suitable habitat it provides during the open-water period (i.e., composed entirely littoral habitat with dense

aquatic vegetation) combined with variable overwintering conditions that result in regular occurrences of poor winter dissolved oxygen levels. As observed in the Kearl Lake five-year baseline monitoring summary (Golder 2013a), Kearl Lake exhibited a year-over-year increase in CPUE from 2009 to 2011 to the maximum level shown in Figure 5-16, followed by a large drop in 2012 to the minimum level shown in Figure 5-16. This was considered to represent poor overwintering conditions and reduced fish survival during the winter of 2011/2012.

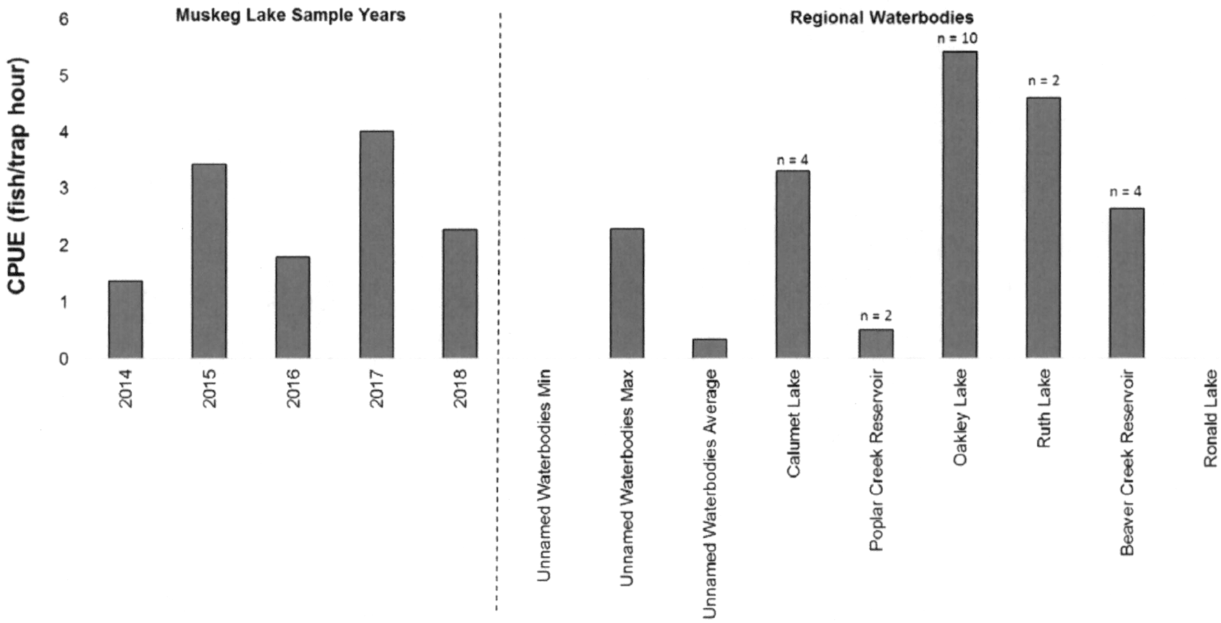
Expectations for Muskeg Lake are that the fish population abundance and biomass will be stable in comparison to Kearl Lake, as the lake provides secure overwintering habitat and eliminates issues with winter fish survival. The BPUE values are generally in the range or around average of Kearl Lake for forage fish, with the BPUE values for large-bodied fish being higher in Muskeg Lake than in Kearl Lake due to development of the Northern Pike and White Sucker populations in Muskeg Lake that are limited in Kearl Lake by its less suitable habitat conditions. Although the results indicate that some forage fish that overwinter in Muskeg Lake migrate to Kearl Lake for the summer, the forage fish BPUE data shows that productivity in Muskeg Lake in the summer is in the range of that in Kearl Lake, and has been since 2014, the year the connector channel was opened. Further increases in forage fish CPUE/BPUE in Muskeg Lake are possible as the aquatic macrophyte cover in the littoral zone continues to increase in extent and density (see Section 5.4.1), providing habitat that is highly suitable for forage fish as indicated by the minnow trapping results for this meso-habitat (Table 5-23).

5.4.4.4 Regional Waterbody Comparison

Fish populations in Kearl Lake are limited by the lack of a pelagic zone and secure overwintering habitats. The five-year baseline monitoring study for Kearl Lake showed suckers present in low abundance, an absence of Northern Pike, and forage fish abundance fluctuating with variable overwintering conditions (Golder 2013a). Therefore, comparisons were made between the current level of development of Muskeg Lake fish populations and other regional waterbodies. Attempts were made to find regional waterbodies similar in size to Muskeg Lake and lakes with pelagic overwintering habitats. Due to limitations in the available data-set, it was necessary to include some small waterbodies lacking pelagic habitat, some waterbodies that are much larger than Muskeg Lake, and some mature man-made waterbodies. Due to limited reporting of fish sampling efforts and lack of reporting of fish weight data in the regional data-set, CPUE comparisons were limited and BPUE comparisons were not possible.

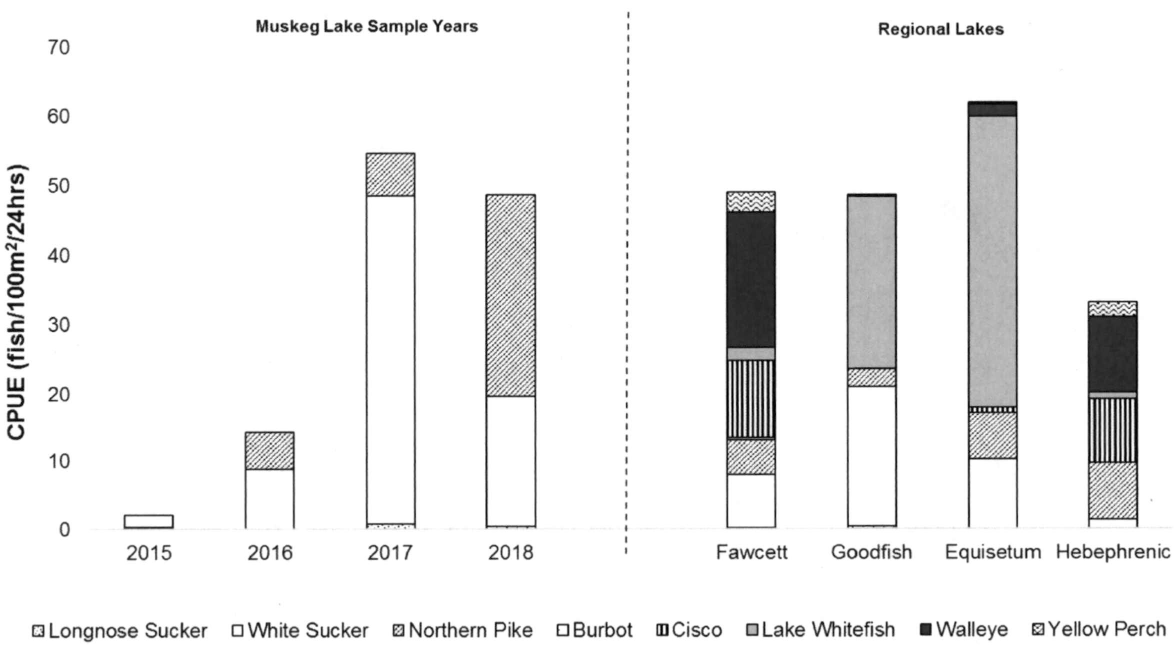
Regional CPUE data was obtained from multiple baseline and monitoring reports for the oil sands and Northern Boreal Forest Region. A total of six large waterbodies (Ronald Lake, Oakley Lake, Calumet Lake, Beaver Creek Reservoir, Ruth Lake and Poplar Creek Reservoir) and a group of 21 Unnamed Waterbodies provided comparisons for minnow trapping data in Muskeg Lake – all the waterbodies are located within a 315 km radius of Muskeg Lake and were sampled between 2003 and 2014. A total of four waterbodies (Fawcett Lake, Goodfish Lake, Hebephrenic Lake and Equisetum Lake) provided comparisons for gill netting data in Muskeg Lake – all the waterbodies are located within a 665 km radius of Muskeg Lake and were sampled in 2000.

Catch-per-unit-effort (CPUE) for minnow trapping (Figure 5-20) and gill netting (Figure 5-21) in Muskeg Lake from 2014 to 2018 was compared to regional CPUE data from lakes found within the Northern Boreal Forest region in Alberta, including natural and man-made waterbodies. Due to regional reporting methods, Muskeg Lake gill netting results were converted from fish/net-hour to fish/100 m^2/24-hours for comparison purposes.



Note: Regional waterbodies appear on x-axis according to size (smallest to largest - left to right); CPUE = Catch-per-unit-effort; n = number of years sampled

Figure 5-20: Regional CPUE Comparisons for Minnow Trapping in Muskeg Lake, 2014 to 2018



Note: Regional lakes appear on x-axis according to size (smallest to largest - left to right); CPUE = Catch-per-unit-effort

Figure 5-21: Regional CPUE Comparisons for Gill Netting in Muskeg Lake, 2015 to 2018

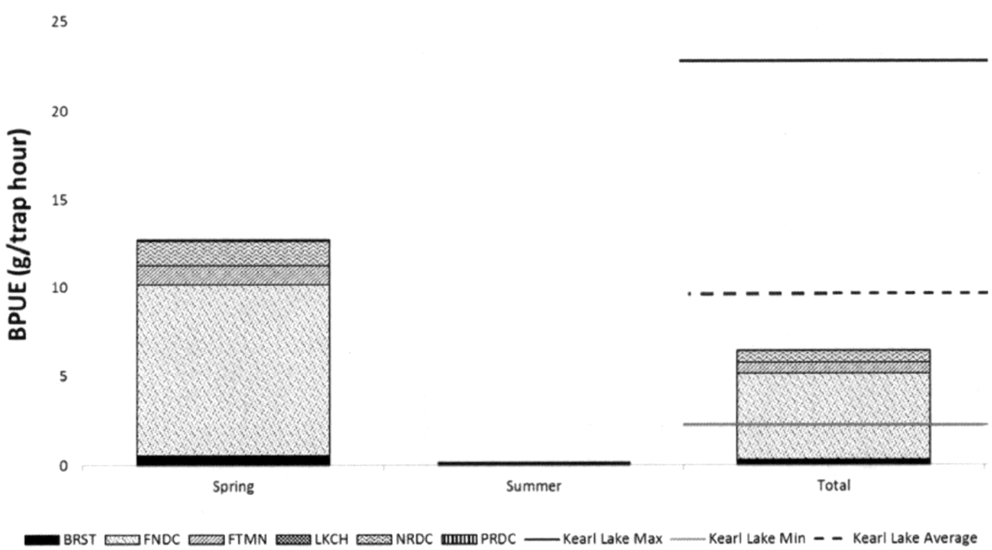
Minnow Trapping data shows that Muskeg Lake total CPUE for 2014 to 2018 was similar to that of the regional waterbodies, including waterbodies without pelagic habitats (unnamed waterbodies and Oakley Lake) and the larger waterbodies that contain pelagic overwintering habitats. Muskeg Lake shows a maximum total CPUE of 4.03 fish/trap-hr (in 2017), which is higher than the total CPUE for most regional waterbodies with exception of Oakley Lake (9.7 fish/trap-hr) and Ruth Lake (4.61 fish/trap-hr). These results indicate a well-developed forage fish community in Muskeg Lake, particularly in consideration that Muskeg Lake supports a population of Northern Pike while the regional waterbodies (except for Ronald Lake) lack predatory fish.

Gill netting total CPUE for Muskeg Lake from 2014 to 2018 increased to a level that is also comparable to that of natural regional waterbodies. Muskeg Lake CPUE in 2015 and 2016 for large-bodied species was lower than that of the regional waterbodies, as the lake was in the early stages of colonization, while total CPUE in 2017 and 2018 was similar to that found in the natural lakes. This is the case even though the regional waterbodies have a greater number of large-bodied fish species (5 to 8 species) compared to Muskeg Lake (3 species). With respect to comparisons of total CPUE for the individual populations of large-bodied fish in Muskeg Lake, longnose sucker was present only in Muskeg Lake, White Sucker CPUE was higher (2017) or equal (2018) to each of the regional waterbodies, and Northern Pike CPUE was similar (2017) or higher (2018) than all the regional waterbodies.

5.5 Kearl Lake Fish Populations

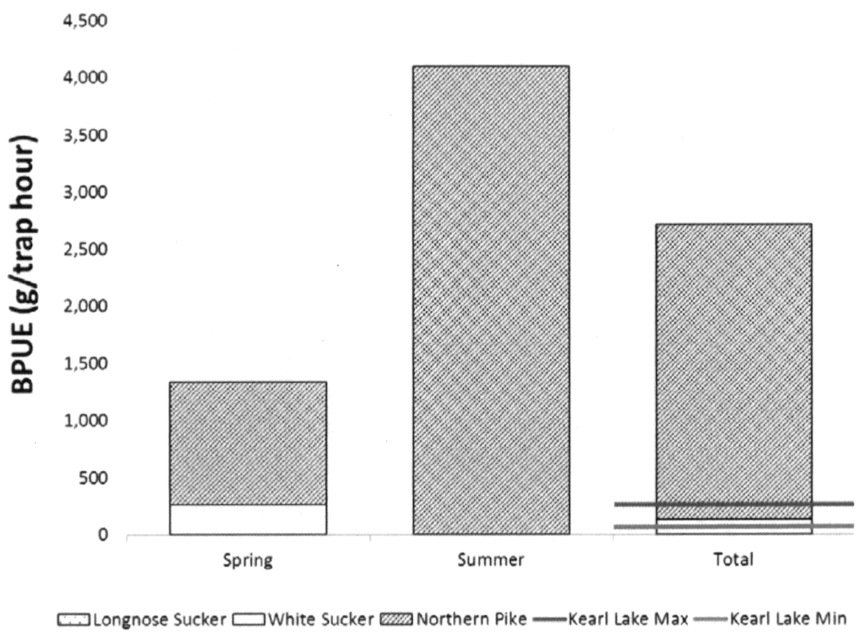
Kearl Lake was sampled for fish in 2018 to see how the current fish populations compare to baseline conditions established prior to the connection with Muskeg Lake. This is the first sampling event in Kearl lake since the connector channel was opened. Kearl Lake was sampled for five consecutive years to gather baseline data from 2009 to 2013, prior to opening the connector channel with Muskeg Lake in 2014. The 2018 survey was conducted five years after the last baseline survey.

Biomass-Per-Unit-Effort have been graphed for minnow trapping (Figure 5-22) and gill netting (Figure 5-23) data form Kearl Lake in 2018. Kearl Lake maximum, average and minimum range lines for total BPUE from baseline conditions have been included in order to allow for comparisons of Kearl Lake prior to the connector channel being opened.



Note: BPUE = Biomass-per-unit-effort; g = gram; BRST = Brook Stickleback; FNDC = Finescale Dace; FTMN = Fathead Minnow; LKCH = Lake Chub; NRDC = Northern Redbelly Dace; PRDC = Pearl Dace; g = gram; Max = maximum; Min = minimum

Figure 5-22: Summary of Relative Biomass for Minnow Trapping in Kearl Lake, 2018



Note: g = gram; Max = maximum; Min = minimum

Figure 5-23: Summary of Relative Biomass for Gill Netting in Kearl Lake, 2018

BPUE for minnow trapping in 2018 was above average compared to baseline levels in the spring sampling event and was below the range of baseline levels in the summer sampling event. The total combined BPUE for both seasons in 2018 was within the range found during baseline conditions (2009 to 2013).

The BPUE results for large-bodied fish species in Kearl Lake (Figure 5-23) show a large increase in values from baseline conditions. Large-bodied fish BPUE has seen a 10-fold increase over what was observed during baseline conditions. This was mainly due to the presence of Northern Pike in Kearl Lake, as Northern Pike was not found in the lake during baseline sampling. As a benefit of Muskeg Lake construction, it was intended that Northern Pike would be able to establish a permanent population in Kearl Lake as a result of the connection to Muskeg Lake and its secure overwintering habitat.

5.6 Comparison of Muskeg Lake Development to Design Predictions

Design parameters and predictions regarding the development and expected productivity of Muskeg Lake were provided in the Kearl No Net Loss Plan (NNLP) (Imperial Oil 2007). The NNLP includes the physical design parameters for the lake basin as well as modelling of expected conditions for hydrology, water quality and fish habitat suitability. This section provides a comparison of the Muskeg Lake monitoring data to the modelling predictions.

5.6.1 Physical Characteristics

As-built specifications of the Muskeg Lake basin were prepared following lake construction (i.e., excavation of the lake basin and installation of fish habitat features). Differences between the NNLP design and the as-built specifications occurred due to site conditions encountered during construction and general optimizing activities. These differences were examined in relation to the predicted amount of compensation habitat to be provided by the lake (Golder 2010b) and it was concluded that despite some changes from design, the as-built lake was considered to be equivalent to the design with respect to the provision of a suitable quantity and quality of fish habitat for the seven fish species targeted for the Muskeg Lake fish community. The differences between design and as-built specifications include the following.

- Total surface area of the lake was expanded from the design specification of 300,000 m^2 to 303,642 m^2 (increase of 1.2%) due to slight footprint modifications needed to move the compensation lake further from Kearl Lake to prevent any possible slope failure or piping of water, and incorporation of a decommissioned lake-side sediment pond into the lake basin.
- The specific bathymetry distribution differed from design specifications resulting in an increase in littoral habitat area (zone 3 m deep or less), a decrease in the area 3 to 5 m deep, and an increase in the area deeper than 5 m. Overall, the littoral zone increased from 15.6 to 23.4% of the total lake area, while the maximum depth (7 m) and average depth (4 m) remained as per the design. In addition to providing the as-built specifications, detailed bathymetric analysis and mapping was completed for Muskeg Lake as part of the monitoring program (Golder 2015).
- The specified amounts of rocky substrate (gravel, cobble, boulder) were installed as per the design, but some placements varied from design with respect to their exact locations; however, the total area of rock and locations within the appropriate depth zones were as per the design.
- Large woody debris structures and root wad structures were installed as per the design.

The as-built specifications for Muskeg Lake were used to conduct habitat suitability index (HSI) modelling to compare the estimated productivity of the as-built lake to the NNLP design (see Section 5.6.8).

5.6.2 Hydrology Modelling

Hydrology modelling was conducted in the NNLP as part of the hydrologic feasibility and sustainability analysis for predictions related to water level fluctuations, as they pertain to the development and maintenance of stable and productive aquatic habitats in the lake.

5.6.2.1 Water Level

The hydrology assessment in the NNLP predicted that the combined Kearl-Muskeg lakes system would have stable water levels, with fluctuations typical for natural lakes in the region, facilitating development of a stable and productive littoral zone in Muskeg Lake. The evaluation of current water level data for the Kearl-Muskeg lakes system (Section 3.5.3.1) indicates that Muskeg Lake maximum water level fluctuations to date have been less than 0.6 m, matching the prediction that fluctuations over the long-term would be 1.0 m or less. Muskeg Lake has had a stable water level since filling and data from the fish and fish habitat surveys show the lake has developed stable and productive riparian and littoral zones, with an expanding riparian and aquatic vegetation.

5.6.2.2 Shoreline Stability

A potential issue with shoreline stability was identified during stakeholder review of the Kearl NNLP related to possible wind-driven erosion along the windward side of the Muskeg Lake shore in the early stages of development due to the presence of erodible materials and lack of mature vegetation. Shoreline erosion could affect shoreline stability and local suspended sediment levels in the lake, possibly resulting on some degradation of aquatic habitat. To address this concern, rocky substrates to be installed in the near-shore littoral zone were placed on the windward side of the lake to add shoreline protection while riparian and aquatic vegetation was becoming established, and to maximize the quality of the rocky areas as spawning and egg incubation habitat. In addition, monitoring of shoreline stability was included in the Kearl SWFM Plan (Imperial Oil 209a), with shoreline stability evaluated as part of fish habitat mapping.

The habitat mapping to date shows all shoreline areas of Muskeg Lake to be stable with no wind-driven erosion issues and continuing development of aquatic and riparian vegetation. Imperial did identify one location in the riparian zone where gullying was observed due to overland drainage. To mitigate potential erosion issues, the gully area was stabilized and armoured to prevent further erosion.

5.6.3 Water Quality Modelling

Water quality modelling was conducted for Muskeg Lake in the NNLP for predictions related to key parameters and lake characteristics related to aquatic habitat productivity and for model-specific inputs for fish HSI modelling.

5.6.3.1 Nutrients and Trophic Status

As described in water quality assessment (Section 4.9.1), based on nutrient levels, Muskeg Lake has transitioned from oligotrophic to mesotrophic status over the development period to date and currently has a similar trophic status to Kearl Lake. This matches the NLLP prediction for the early stages of the lake, with the lake expected to trend towards meso-eutrophic status in the future.

5.6.3.2 Temperature

As described in water quality assessment (Section 4.9.2), winter temperatures measured in Muskeg Lake match the NNLP predictions. For summer temperatures, assessment of the continual temperature recordings from the datasondes deployed during the open water periods from 2014 to 2018 show average summer temperatures to be 19.1°C, the range of maximum weekly summer temperatures to be 22.4°C to 23.2°C, and the maximum peak temperatures to be 22.9°C to 25.2°C. These measurements confirm the NNLP model prediction of an average summer temperature of 19°C and are similar to the predicted maximum summer temperature of 24.5°C.

5.6.3.3 pH

The NNLP does not provide specific predictions for pH in Muskeg Lake but assumes the pH range will be the same as Kearl Lake, with the pH range of 6 to 9 used as the input for fish HSI modelling. The datasonde records for Muskeg Lake show a pH range of 7.5 to 9.1 for all monitoring years combined, matching the NNLP modelling inputs.

5.6.3.4 Dissolved Oxygen

As described in the water quality assessment (Section 4.9.3), the seasonal dissolved oxygen measurements show that Muskeg Lake matches the NNLP model predictions, being greater than 7 mg/L. Continual open-water data from the datasondes deployed for fish habitat monitoring also show open-water dissolved oxygen to be generally 7.2 mg/L or higher. However, during one or two week long periods in summer 2017 and 2018 the

datasondes showed an increase in diurnal fluctuations (difference between daily minimum and maximum DO), with average dissolved oxygen levels dipping to 6.0 mg/L.

The NNLP modelling predicted late winter dissolved oxygen in Muskeg Lake to be 0 mg/L within 1 m of the lake bed and to exceed 5 mg/L in the rest of the water column (Imperial Oil 2007). As described in Section 4.9.3., the monitoring data indicates that the dissolved oxygen predictions were accurate for most years, with dissolved oxygen levels of 5 mg/L to 11 mg/L in the mid to upper water column, and as low as 0.67 near the lake bed. In 2018 however, dissolved oxygen concentrations were less than 5 mg/L in the mid water column (Figure 4-27), although they were 5 mg/L or higher in the upper water column and were higher than predicted near the lake bed (2.2 mg/L).

Overall, measured dissolved oxygen levels show a greater degree of variability than predicted in the NNLP. Open-water dissolved oxygen levels were both higher and lower at times than the predicted primary range of 7.2 to 8.2 mg/L, and were higher at times than the overall range of 5 to 9.5 mg/L. In the winter, the under-ice depth to which dissolved oxygen levels of 5 mg/L or higher were maintained was sometime less than predicted, while dissolved oxygen levels at the lake bottom were sometimes higher than predicted. In all years, Muskeg Lake, including the majority of lake depths in the winter, provided dissolved oxygen levels highly suitable for the target fish community of forage fish, Norther Pike, Yellow Perch and White Sucker (NRBS 1994; Golder 2008).

5.6.3.5 Total Dissolved Solids (TDS)

As described in the water quality assessment (Section 4.9.4), TDS concentrations in Muskeg Lake after filling were in the range of 150 to 250 mg/L, most recently stabilizing at approximately 200 mg/L. The current TDS levels in Muskeg Lake are somewhat lower than the predicted range of approximately 230 to 245 mg/L for the Phase I lake but are within the range of values for Kearl Lake, as predicted. All TDS values measured in Muskeg Lake are in the optimal range of suitability for the fish species for which TDS is an HSI model variable.

5.6.3.6 Mercury

Predictions for mercury levels in Muskeg Lake were not included in the NNLP. However, a mercury summary is provided here due to the concern with potential increases in mercury in fish tissue that have been documented to occur in some constructed and flooded waterbodies, mainly due to methylation of mercury from decomposition of inundated organic material making mercury available to the aquatic food chain. The 2012 to 2018 monitoring data shows that total mercury levels in Muskeg Lake water were similar to, and slightly lower, than Kearl Lake, while methyl mercury was below detection limits in both lakes and total mercury in Muskeg Lake sediment was also below detection limits. The monitoring data demonstrates that there has been no increase in mercury or bio-available mercury in Muskeg Lake due to flooding of the basin. This is likely due to the fact that the lake was created by excavation, removing vegetation and organic soil prior to flooding, a key mitigation measure to prevent mercury increases.

5.6.4 Aquatic Macrophytes

As described in Section 5.4.1, monitoring has demonstrated continual colonization and expansion of the distribution and density of littoral vegetation in Muskeg Lake. The current vegetation development level has not reached the average littoral density of 57% predicted in the NNLP, but further vegetation development is expected to continue through both new colonization and expansion of existing stands and is expected to reach the predicted level as the lake matures.

5.6.5 Plankton Communities

The NNLP does not provide a prediction for plankton community development for Muskeg Lake, but the monitoring data to date indicates plankton development was rapid. Phytoplankton communities began development during the filing process and were immediately within the range of levels recorded in Kearl Lake, while zooplankton development was slower, taking four years to reach levels comparable to Kearl Lake.

5.6.6 Benthic Invertebrate Communities

The general prediction provided in the NNLP regarding development of the benthic invertebrate communities in Muskeg Lake was that it would require one to five years to achieve levels comparable to natural environments. The monitoring data indicates that Muskeg Lake benthic invertebrate colonization began during the filling phase, followed by rapid colonization and development of the benthic invertebrate community in the littoral zone and slower development in the pelagic zone. Littoral benthic invertebrate density and richness levels in Muskeg Lake were similar to or higher than Kearl Lake levels within two years of filling, matching the NNLP prediction. In addition, invertebrate densities within the post-colonization phase of Muskeg Lake were comparable to some neighboring regional lakes but were lower than the larger regional lakes. Benthic invertebrate taxonomic richness within the littoral habitat of Muskeg Lake was greater than the average richness recorded for other regional waterbodies.

5.6.7 Fish Populations

The development of fish populations in Muskeg Lake has occurred fairly rapidly over the first five years since the lake connector channel was opened to allow fish colonization from Kearl Lake. Fish species diversity is high in Muskeg Lake, with all fish species currently or historically documented to be present in Kearl Lake now also present in Muskeg Lake, providing the maximum species diversity that is achievable through colonization. This includes all six of the seven fish species targeted for inclusion in the Muskeg Lake community in the NNLP that are present in the Kearl Lake/Muskeg Creek drainage area. The seventh fish species targeted for the fish community in the NNLP (Yellow Perch) is not present in Kearl Lake or in the drainage basin. As identified in the NNLP, Yellow Perch would require stocking to become part of the Muskeg Lake fish community.

Fish size and condition in Muskeg Lake were similar to that in Kearl Lake, as expected. Condition factors were good for Muskeg Lake fish, ranging from just under 1.0 for two species to higher than 1.0 for all remaining species. Average fish weights were also good in Muskeg Lake, being comparable to Kearl Lake for forage fish and higher than Kearl Lake for Longnose Sucker, White Sucker and Northern Pike.

Fish abundance (as represented by CPUE) and biomass (as represented by BPUE) have developed well in Muskeg Lake. Forage fish populations developed rapidly, achieving CPUE and BPUE levels comparable to Kearl Lake the year of connector channel opening and the following year, respectively. Forage fish CPUE levels in Muskeg Lake are also comparable to other regional natural/mature waterbodies. Large-bodied fish populations developed more slowly than did forage fish, which was expected based on the low abundance of suckers and general absence of Northern Pike in Kearl Lake due to the lake's lack of pelagic habitat. Nonetheless, the abundance and biomass levels of the large-bodied fish community exceeded those of Kearl Lake within three years of connector channel opening. Currently, Muskeg Lake supports a large-bodied fish community, and in particular Northern Pike and White Sucker populations, with CPUE levels comparable to the examined natural regional lakes that also provide deep-water pelagic habitats.

5.6.8 Fish Habitat Suitability Index (HSI) Modelling

Fish habitat suitability index (HSI) models have been developed for the Alberta oil sands region (Golder 2008) to assist with determination of habitat quality for natural habitats and for planned habitats to be constructed to compensate for alterations of natural habitats. HSI values are used in conjunction with measures or estimates of habitat quantity (i.e., surface area) to provide a quantification of the estimated habitat productivity in the relevant habitats. Habitat productivity is represented by Habitat Units, calculated as: HUs = HSI x surface area (m^2). HSI models are species-specific and values are calculated individually for each relevant fish species, with the individual HUs summed to provide the total HUs for a given area of habitat. The Kearl NNLP (Imperial Oil 2007) provided HSI and HU calculations for all affected habitats and for the compensation habitat to be developed in Muskeg Lake. To provide the specified amount of compensation for the affected HUs, Muskeg Lake is designed to provide a specific amount of HUs for the fish species expected to form the fish community. This section provides calculations of the HSI values and HUs provided to date by Muskeg Lake in relation to the modelled predictions in the NNLP.

To show the trajectory of habitat development and the current maturity level of Muskeg Lake, HSI determinations have been calculated for the last three years of monitoring data (2016, 2017 and 2018). The Muskeg Lake values were then compared to the modelled HSI values and HUs from the NNLP to gauge the degree to which the lake matches the predictions and to identify the specific habitat components that need further developmental time.

The HSI models each consist of a number of habitat variables, representing the physiochemical and biological characteristics of the lake, with defined ranges of suitability used to assign the Suitability Index (SI) for the variable. As specified by the requirements of the various HSI models, SI modelling input data was provided by the design specifications and monitoring results as follows.

- Hydrology
  - summary of Kearl-Muskeg lakes water levels
- Water Quality (seasonal profile measurements and continuous datasonde records):
  - pH
  - water temperature
  - dissolved oxygen
  - TDS
  - trophic status
- Fish Habitat
  - lake bathymetry
  - aquatic vegetation distribution and density
  - habitat cover features – boulder gardens, large woody debris structures and root wad structures
  - substrate composition and distribution

SI values for each variable range from 0.0 (no suitability) to 1.0 (optimal suitability). The HSI models identify how the multiple SI values are to be used to calculate a total HSI for each species (Golder 2008), with HSI values also ranging from 0.0 to 1.0. The values for each SI variable were obtained from the as-built specifications and the monitoring measurements conducted in Muskeg Lake. The HSI values were calculated individually for each of the seven species identified in the NNLP for the Muskeg Lake fish community, as well as the three additional species that have colonized Muskeg Lake. The HSI values were calculated for each individual species for each of the three years of monitoring data (2016, 2016 and 2018) to show how the lake has developed over time. Each fish species is represented by the lacustrine (waterbody) component of the relevant HSI model.

The conditions of the various habitat parameters used in the HSI models are based on the data collected in each monitoring years (2016, 2017 and 2018). The HSI values were then compared to predicted HSI values in the NNLP (Table 5-34). The HSI values were used in combination with the as-built surface area of Muskeg Lake to obtain the habitat units (HUs) provided. The predicted HSI values and HUs for Muskeg Lake are presented as they were in the NNLP, using the design surface area of Muskeg Lake. The detailed HSI modelling results for Muskeg Lake are presented in Appendix X.

The productivity of Muskeg Lake, as represented by the total number of HUs, increased from 2016 to 2018 (Table 5-23). As of 2018, Muskeg Lake is estimated to provide 1,093,112 HUs for the seven species identified in the NNLP, which is 89% of the 1,230,000 HUs the lake is expected to provide at maturity for these species. Additional HUs were also calculated to be present in Muskeg Lake for the three other species that have colonized the lake (Table 5-23).

The Muskeg Lake HSI values for one species (White Sucker) have met the NNLP modelled expectation of 0.74 since 2016, while HSI values for the remaining six target species have shown an increase over the three-year monitoring period (2016 to 2018). HSI values for all four of the target forage fish species (Brook Stickleback, Fathead Minnow, Lake Chub and Pearl Dace) reached the NNLP modelled expectations by 2017 or 2018, depending on the species. Further increases in habitat suitability will occur in Muskeg Lake for the forage fish species relative to the SI for littoral cover, as aquatic vegetation distribution and density continues to develop (Section 5.5.1), but the overall HSI values for these species will not increase as they are limited by existing lake bathymetry or substrate composition. Although Northern Pike HSI increased over time from 0.16 to 0.40, the 2018 value has not yet achieved the NNLP modelled expectation of 0.50. The HSI value for Northern Pike is currently limited by the level of aquatic vegetation development in the lake (Appendix X) and is therefore expected to reach the modelled prediction given further developmental time. The HSI value for Yellow perch (0.30), a species not present in Muskeg Lake but considered for future stocking, is lower than the NNLP modelling prediction of 0.70. Habitat suitability for Yellow Perch is currently limited by spring water temperatures appearing to be too warm. However, water temperatures have only been monitored in Muskeg Lake in the late spring. Therefore, advancing the installation of the water quality datasondes to occur immediately after ice-out in the spring is recommended for future monitoring. It is expected that obtaining temperature records for the entire spring period would show a higher suitability for this species.

Table 5-34: Habitat Suitability Index Values for Muskeg Lake, 2016 - 2018

Species	Year	HSI	HU[(b)]	NNLP Modelled Values		Difference 2018 HU – Modelled HU
				HSI	HU[(c)]	
Species Modelled as Part of the NNL Plan						
Brook Stickleback	2016	0.25	75,910	0.52	156,000	1,894
	2017	0.50	151,821			
	2018	0.52	157,894			
Fathead Minnow	2016	0.25	75,910	0.52	156,000	1,894
	2017	0.50	151,821			
	2018	0.52	157,894			
Lake Chub	2016	0.50	151,821	0.60	180,000	2,185
	2017	0.60	182,185			
	2018	0.60	182,185			
Pearl Dace	2016	0.50	151,821	0.52	156,000	1,894
	2017	0.52	157,894			
	2018	0.52	157,894			
White Sucker	2016	0.74	224,695	0.74	222,000	2,695
	2017	0.74	224,695			
	2018	0.74	224,695			
Northern Pike	2016	0.16	48,583	0.50	150,000	-28,543
	2017	0.16	48,583			
	2018	0.40	121,457			
Yellow Perch[(a)]	2016	0.10	30,364	0.70	210,000	-118,907
	2017	0.10	30,364			
	2018	0.30	91,093			
Total	2016	2.50	759,104	4.1	1,230,000	-136,888
	2017	3.12	947,363			
	2018	3.60	1,093,112			
Colonizing Species not Modelled as Part of the NNL Plan						
Finescale Dace	2016	0.25	75,910	n/m	n/m	157,894
	2017	0.50	151,821			
	2018	0.52	157,894			
Northern Redbelly Dace	2016	0.25	75,910	n/m	n/m	157,894
	2017	0.50	151,821			
	2018	0.52	157,894			
Longnose Sucker	2016	0.61	185,222	n/m	n/m	209,513
	2017	0.69	209,513			
	2018	0.69	209,513			

(a) Yellow Perch not currently present; (b) HU = HSI x As-built Lake Surface Area (303,642 m^2); (c) HU = HSI x Design Lake Surface Area (300,000 m^2)
Note: HSI = Habitat Suitability Index, Hus = Habitat Units; n/m = not modelled as part of No Net Loss Plan

6.0 2019 MONITORING PROGRAM

6.1 Hydrology Program

Currently, the planned 2019 hydrology program will include continued monitoring of the four hydrometric stations and one climate station used in 2018 (K6, K9, K10, K11 and C4). Monitoring in 2019 will continue to be conducted in all seasons (i.e., winter, spring, summer and fall). Potential future adjustments to the hydrology monitoring program are discussed in Section 6.4.1.

6.2 Water and Sediment Quality Program

The 2019 water quality program will be similar to the 2018 program and will include continued seasonal monitoring (i.e., winter, spring, summer and fall) at Imperial operated stations on the Muskeg River (MR-2) and the Firebag River (FR-1), as well as monitoring at former regional (RAM or AEP) monitoring stations on the Muskeg River (MUR-6 and AB07DA0440), Wapasu Creek (WAC-1), Iyinimin Creek (IYC-1) and in Kearl Lake (KEL-1). Seasonal (i.e., winter, spring, and late summer) water quality monitoring will also be conducted in Muskeg Lake (NNL-1).

The 2019 sediment quality program will include continued fall monitoring at the stations located downstream of the Kearl area, including the Muskeg River (AB07DA0440), Wapasu Creek (WAC-1) and the Firebag River (FR-1). Late summer sediment monitoring will also be conducted in Muskeg Lake (NNL-1) and Kearl Lake (KEL-1).

6.3 Fish and Fish Habitat Program

The 2019 fish and fish habitat monitoring program will consist of monitoring of Muskeg Lake but will not include monitoring in Kearl Lake, which is next scheduled to be sampled in 2023. Monitoring of the biological development of Muskeg Lake will continue in 2019 and will include components for which monitoring was conducted in 2014 to 2018 (i.e., macrophytes, plankton, benthic invertebrates and fish populations). Aquatic macrophytes sampling will expand to a more quantified assessment of general vegetation development using transects and quadrat plots. Further testing will be conducted for suitable meso-habitat specific fish population estimate methods for future use in estimating meso-habitat and whole lake biomass densities.

The main monitoring surveys in 2019 will continue to be scheduled to occur in the spring (late May/early June) and late summer (late August/early September), with the addition of an early spring visit to install the water quality datasondes shortly after ice-out and a mid summer (July) visit for datasonde maintenance.

6.4 Recommendations for Monitoring Program Adjustments

6.4.1 Hydrology

In 2019, a few minor changes to the hydrology monitoring program are recommended. The air temperature sensor at Climate Station C4 and/or its datalogger need to be examined to determine if replacement is needed. The air temperature sensor will be replaced in 2019.

Hobo loggers and a barologger should continue to be installed at the stations every spring to provide a back-up water level data source in the event of damage or communication issues with the primary CFB gauges. The Hobo logger installed at the K10 on the Firebag River needs to be better anchored to the river bed so that it can sustain higher flow conditions. Additionally, one of the Hobo loggers malfunctioned in 2018 and will be replaced with a new logger.

Monitoring at the remote K10 Firebag River station has been a challenge over the years due to access issues, with successful access in 2018 via helicopter and will need to continue in 2019. High flow or ice conditions have made discharge monitoring a safety issue on occasion at this station. As high flows are typical in the spring, use of a motorized boat and ADCP River Surveyor equipment to monitor the river flows should be investigated to increase the reliability of obtaining manual flow measurements in the spring. As Imperial requires a boat safety watch, an additional boat and crew would be required. Obtaining the higher flow measurements will provide additional confidence in the stage-discharge rating curve data.

6.4.2 Water and Sediment Quality

Recommendations for the water and sediment quality monitoring program consist of investigating alternate locations for Station MR-2 due to current poor access conditions. Alternate locations would maintain the station objectives of being located on the upper Muskeg River in the project air emissions pathway.

6.4.3 Fish

With the establishment of large-bodied fish populations in Muskeg Lake, it is recommended that an early spring site visit be added to the 2019 monitoring program to facilitate installation of the water quality datasondes immediately after ice-out to provide a full record of spring water temperatures to better assess habitat suitability for spring spawning species, and that fish ageing and fish tagging be initiated for large-bodied fish.

Golder Associates Ltd.

https://golderassociates.sharepoint.com/sites/102392/deliverables/2018nnl_report/2018 annual report_draft_review comments_25mar.docx

7.0 REFERENCES

AEMERA (Alberta Environmental Monitoring, Evaluation and Reporting Agency). 2016. Regional Aquatics Monitoring Program – Joint Oil Sands Monitoring Plan (Report no. AEM7250.2). Available at: http://www.ramp-alberta.org/UserFiles/File/AnnualReports/2015/JOSMP_2015_Final_TOC_ and_ Executive_Summary.pdf.

Alberta Environment. 2008. Muskeg River Interim Management Framework for Water Quantity and Water Quality: Management Guidance for Aquatic Components of the Muskeg River Watershed. June 2008.

AEP (Alberta Environment and Parks). 2018. AEP Water Data System. AEP SWQ Requests. Edmonton, AB.

Berg P, Pace M. 2017. Continuous measurement of air-water gas exchange by underwater eddy covariance. Biogeosciences Discussion: 1-27.

CCME (Canadian Council of Ministers of the Environment). 1998. Canadian sediment quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg.

EMAN-North (Northern Ecological Monitoring and Assessment Network). 2005. Northern Waters: A Guide to Designing and Conducting Water Quality Monitoring in Northern Canada. Northern Ecological Monitoring and Assessment Network.

GOA (Government of Alberta). 2018. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta.

Golder (Golder Associates Ltd.). 2008. Fish Species Habitat Suitability Index Models for the Alberta Oil Sands Region. Version 2. 0. October 2008.

Golder. 2010a. *Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report – 2010.* Prepared for Imperial Oil Resources Ventures Limited, Calgary, AB. December 2010.

Golder. 2010b. Kearl Compensation Lake – Comparison of Design and As-Built Specifications. Memorandum 08-1345-0026. September 2010.

Golder. 2011. *Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report – 2011.* Prepared for Imperial Oil Resources Ventures Limited, Calgary, AB. December 2011.

Golder. 2012. *Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report – 2012.* Prepared for Imperial Oil Resources Ventures Limited, Calgary, AB. December 2012.

Golder. 2013a. Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report – 2013. Prepared for Imperial Oil Resources, Calgary, AB. December 2013.

Golder. 2013b. Imperial Oil Muskeg Lake Vegetation Planting Program. Prepared for Imperial Oil Resources, Calgary, AB. October 2013.

Golder. 2014. Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report – 2014. Prepared for Imperial Oil Resources, Calgary, AB. December 2014.

Golder. 2015. *Kearl Oil Sands Surface Water and Fish Monitoring Plan Annual Report – 2015.* Prepared for Imperial Oil Resources, Calgary, AB. December 2015.

Golder. 2017a. *Kearl Oil Sands Surface Water and Fish Monitoring Plan Annual Report – 2016.* Prepared for Imperial Oil Resources, Calgary, AB. January 2017.

Golder. 2017b. *Kearl Oil Sands Surface Water and Fish Monitoring Plan Annual Report – 2017.* Prepared for Imperial Oil Resources, Calgary, AB. December 2017.

HC (Health Canada). 2017. Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Health Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Imperial Oil (Imperial Oil Resources Ventures Limited). 2005. Kearl Oil sands Project – Mine Development. Integrated Application and Environmental Impact Assessment – Volume 6: Water. Submitted to the Alberta Energy and Utilities Board and Alberta Environment. July 2005.

Imperial Oil. 2007. *Kearl Oil Sands Project – Mine Development No Net Loss Plan*. Submitted to Fisheries and Oceans Canada. Prepared by Imperial Oil Resources Ventures Limited in association with Golder Associates Ltd. Calgary, AB.

Imperial Oil. 2009a. *Kearl Oil Sands Project Surface Water and Fish Monitoring Plan.* Prepared by Imperial Oil Resources Ventures Limited in association with Golder Associates Ltd. Calgary, AB.

Imperial Oil. 2009b. *Kearl Oil Sands Project Surface Water and Fish Monitoring Plan Annual Report - 2009.* Submitted to Fisheries and Oceans Canada. Prepared by Imperial Oil Resources Ventures Limited in association with Golder Associates Ltd. Calgary, AB.

James. M.R., M. Weatherhead, C. Stranger, and E. Graynoth, . 1998. Macroinvertebrate Distribution in the Littoral Zone of Lake Coleridge, South Island, New Zealand – Effects of Habitat Stability, Wind Erosion, and Macrophytes. New Zealand Journal of Marine and Freshwater Research, 32:2, 287-305, DOI: 10.1080/00288330.1998.9516826.

JOSMP (Joint Oil Sands Monitoring Plan). 2016. Regional Aquatics Monitoring in Support of the Joint Oil Sands Monitoring Plan 2015 Program Report. Prepared for Alberta Environmental Monitoring, Evaluation and Reporting Agency by Hatfield Consultants, Kilgour and Associates Ltd., and Western Resource Solutions. April 2016.

McNeely R, Neimanis V, and Dwyer L. 1979. Water Quality Sourcebook: A Guide to Water Quality Parameters. Ottawa ON. 33 p.

NRBS (Northern River Basins Study). 1994. Dissolved Oxygen Requirements for Fish of the Peace, Athabasca and Slave River Basins. NRBS Project Report No. 92.

RAMP (Regional Aquatics Monitoring Program). 2018. Water and Sediment Quality Database. Available at: http://www.ramp-alberta.org. Accessed November 2018.

Vollenweider R, and Kerekes J. 1980. "Background and Summary Results of the OECD Cooperative Program on Eutrophication." In: *Proceedings of an International Symposium on Inland Waters and Lake Restoration.* U.S. Environmental Protection Agency. EPA 440/5-81-010. pp. 26-36.

Wetzel R. 2001. Limnology: Lake and River Ecosystems. San Diego CA. 191 p.

8.0 ABBREVIATIONS

Abbreviation	Definition
°C	degrees Celsius
%	percent
<	less than
>	greater than
±	plus/minus
≤	less than or equal to
≥	greater than or equal to
ADV	Acoustic Doppler Velocimeter
AEMERA BOD	Alberta Environmental Monitoring, Evaluation and Reporting Agency Biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
CFB	Constant flow bubbler
cm	Centimeter
CPUE	Catch-per-unit-effort
DFO	Fisheries and Oceans Canada (formerly Department of Fisheries and Oceans Canada)
DL	Detection limit
DO	Dissolved oxygen
DOC	Dissolved organic carbon
e. g.	for example [Latin *exempli gratia*]
EC	Environment Canada
EIA	Environmental Impact Assessment
EPEA	Alberta Environmental Protection and Enhancement Act
EPT	Ephemeroptera, Plecoptera and Trichoptera
ESRD	Alberta Environment and Sustainability Resources Development
FRL	Fish Research Licence
g	Gram
g/day	gram per day
Golder	Golder Associates Ltd.
HSI	Habitat Suitability Index
HSPF	Hydrological Simulation Program-Fortran
i.e.	that is [Latin *id est*]
Imperial	Imperial Oil Resources Limited
ISQG	Interim sediment quality guidelines
JOSMP km	Joint Oil Sands Monitoring Plan kilometer
Kearl	Kearl Oil Sands Development
L	Litre
m	Metre
m^2	square metres
m/s	metres per second
m^3	cubic metres
m^3/s	cubic metres per second
max	Maximum

Abbreviation	Definition
Maxxam	Maxxam Analytics
mg-N	milligrams as Nitrogen
mg-P	milligrams as Phosphorus
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
min	Minimum
ml	milliliter
mm	millimetre
n/a	Not applicable
NAD	North American Datum
No.	Number
org	organisms
PAHs	Polycyclic Aromatic Hydrocarbons
PANHs	Polycyclic Aromatic Nitrogen Hydrocarbons
QA	Quality assurance
QC	Quality control
RAMP	Regional Aquatics Monitoring Program
RAM RSR	Regional Aquatics Monitoring (RAMP + JOSMP) Representative study reach
SD	Standard deviation
SE	Standard error
SWRM	Surface Water and Fish Monitoring
TCU	True Colour Unit
TDS	Total dissolved solids
TKN	Total Kieldahl nitrogen
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids
USGS	United States Geological Service
UTM	Universal Transverse Mercator
WSC	Water Survey Division
wt.	Weight
µg/kg	micrograms per kilogram
µg/L	micrograms per litre
µg/m^3	micrograms per cubic metre
µm	micron or micrometre
µS/cm	microSiemens per centimetre

APPENDIX I

2018 Kearl Hydrometric and Climate Monitoring Data

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
01-May-07	-	-	-	0.0416	-	0.134	-	-	2.663	-	99.709	-
02-May-07	-	-	-	0.0232	-	0.118	-	-	2.661	-	99.693	-
03-May-07	-	-	-	0.0213	-	0.146	-	-	2.693	-	99.693	-
04-May-07	-	-	-	0.0211	-	0.177	-	-	2.709	-	99.687	-
05-May-07	-	-	-	0.0279	-	0.190	-	-	2.711	-	99.682	-
06-May-07	-	-	-	0.0329	-	0.187	-	-	2.698	-	99.673	-
07-May-07	-	-	-	0.0274	-	0.185	-	-	2.695	-	99.671	-
08-May-07	-	-	-	0.0344	-	0.178	-	-	2.677	-	99.666	-
09-May-07	-	-	-	0.0576	-	0.163	-	-	2.645	-	99.656	-
10-May-07	-	-	-	0.0808	-	0.135	-	-	2.611	-	99.65	-
11-May-07	-	-	-	0.0786	-	0.132	-	-	2.591	-	99.651	-
12-May-07	-	-	-	0.0631	-	0.118	-	-	2.553	-	99.65	-
13-May-07	-	-	-	0.0504	-	0.119	-	-	2.531	-	99.653	-
14-May-07	-	-	-	0.0361	-	0.103	-	-	2.456	-	99.647	-
15-May-07	-	-	-	0.0241	-	0.089	-	-	2.392	-	99.642	-
16-May-07	-	-	-	0.0243	-	0.077	-	-	2.328	-	99.64	-
17-May-07	-	-	-	0.0193	-	0.070	-	-	2.227	-	99.634	-
18-May-07	-	-	-	0.0117	-	0.062	-	-	2.151	-	99.631	-
19-May-07	-	-	-	0.0108	-	0.060	-	-	2.096	-	99.627	-
20-May-07	-	-	-	0.0114	-	0.070	-	-	2.062	-	99.632	-
21-May-07	-	-	-	0.0096	-	0.068	-	-	2.021	-	99.631	-
22-May-07	-	-	-	0.0090	-	0.062	-	-	1.960	-	99.625	-
23-May-07	-	-	-	0.0073	-	0.055	-	-	1.890	-	99.622	-
24-May-07	-	-	-	0.0065	-	0.051	-	-	1.839	-	99.619	-
25-May-07	-	-	-	0.0054	-	0.048	-	-	1.783	-	99.617	-
26-May-07	-	-	-	0.0042	-	0.044	-	-	1.728	-	99.614	-
27-May-07	-	-	-	0.0034	-	0.040	-	-	1.650	-	99.612	-
28-May-07	-	-	-	0.0019	-	0.037	-	-	1.587	-	99.611	-
29-May-07	-	-	-	0.0015	-	0.034	-	-	1.477	-	99.608	-
30-May-07	-	-	-	0.0011	-	-	-	-	1.390	-	99.606	-
31-May-07	-	-	-	0.0008	-	-	-	-	1.318	-	99.605	-
01-Jun-07	-	-	-	0.0006	-	-	-	-	1.255	-	99.603	-
02-Jun-07	-	-	-	0.0003	-	-	-	-	1.187	-	99.601	-
03-Jun-07	-	-	-	0.0002	-	-	-	-	1.095	-	99.6	-
04-Jun-07	-	-	-	0.0001	-	-	-	-	1.017	-	99.595	-
05-Jun-07	-	-	-	0.0001	-	-	-	-	0.951	-	99.591	-
06-Jun-07	-	-	-	0.0001	-	-	-	-	0.873	-	99.588	-
07-Jun-07	-	-	-	0.0001	-	-	-	-	0.811	-	99.586	-
08-Jun-07	-	-	-	0.0001	-	-	-	-	0.761	-	99.584	-
09-Jun-07	-	-	-	0.0001	-	-	-	-	0.690	-	99.581	-
10-Jun-07	-	-	-	0.0001	-	-	-	-	0.606	-	99.583	-
11-Jun-07	-	-	-	0.0001	-	-	-	-	0.599	-	99.6	-
12-Jun-07	-	-	-	0.0001	-	-	-	-	0.611	-	99.6	-
13-Jun-07	-	-	-	0.0001	-	-	-	-	0.674	-	99.603	-
14-Jun-07	-	-	-	0.0001	-	-	-	-	0.689	-	99.601	-
15-Jun-07	-	-	-	0.0001	-	-	-	-	0.654	-	99.6	-
16-Jun-07	-	-	-	0.0001	-	-	-	-	0.604	-	99.593	-
17-Jun-07	-	-	-	0.0001	-	-	-	-	0.576	-	99.603	-
18-Jun-07	-	-	-	0.0001	-	-	-	-	0.551	-	99.605	-
19-Jun-07	-	-	-	0.0001	-	-	-	-	0.538	-	99.606	-
20-Jun-07	-	-	-	0.0001	-	-	-	-	0.505	-	99.602	-
21-Jun-07	-	-	-	0.0001	-	-	-	-	0.534	-	99.605	-
22-Jun-07	-	-	-	0.0001	-	-	-	-	0.622	-	99.611	-
23-Jun-07	-	-	-	0.0001	-	-	-	-	0.641	-	99.611	-
24-Jun-07	-	-	-	0.0001	-	-	-	-	0.657	-	99.614	-
25-Jun-07	-	-	-	0.0001	-	-	-	-	0.645	-	99.618	-
26-Jun-07	-	-	-	0.0001	-	-	-	-	0.595	-	99.611	-
27-Jun-07	-	-	-	0.0000	-	-	-	-	0.555	-	99.608	-
28-Jun-07	-	-	-	0.0000	-	-	-	-	0.509	-	99.599	-
29-Jun-07	-	-	-	0.0000	-	-	-	-	0.474	-	99.59	-
30-Jun-07	-	-	-	0.0000	-	-	-	-	0.502	-	99.612	-
01-Jul-07	-	-	-	0.0000	-	-	-	-	0.477	-	99.618	-
02-Jul-07	-	-	-	0.0000	-	-	-	-	0.423	-	99.612	-
03-Jul-07	-	-	-	0.0000	-	-	-	-	0.365	-	99.606	-
04-Jul-07	-	-	-	0.0000	-	-	-	-	0.304	-	99.597	-
05-Jul-07	-	-	-	0.0000	-	-	-	-	0.340	-	99.592	-
06-Jul-07	-	-	-	0.0000	-	-	-	-	0.374	-	99.601	-
07-Jul-07	-	-	-	0.0000	-	-	-	-	0.415	-	99.619	0.010
08-Jul-07	-	-	-	0.0000	-	-	-	-	0.432	-	99.621	0.007
09-Jul-07	-	-	-	0.0000	-	-	-	-	0.392	-	99.622	0.004
10-Jul-07	-	-	-	0.0000	-	-	-	-	0.369	-	99.621	0.002
11-Jul-07	-	-	-	0.0000	-	-	-	-	0.355	-	99.624	0.000
12-Jul-07	-	-	-	0.0000	-	-	-	-	0.324	-	99.622	0.000
13-Jul-07	-	-	-	0.0000	-	-	-	-	0.261	-	99.616	0.007
14-Jul-07	-	-	-	0.0000	-	-	-	-	0.225	-	99.612	0.002
15-Jul-07	-	-	-	0.0000	-	-	-	-	0.375	-	99.63	0.000
16-Jul-07	-	-	-	0.0000	-	-	-	-	0.297	-	99.636	0.000
17-Jul-07	-	-	-	0.0000	-	-	-	-	0.289	-	99.635	0.000
18-Jul-07	-	-	-	0.0000	-	-	-	-	0.286	-	99.633	0.000
19-Jul-07	-	-	-	0.0000	-	-	-	-	0.290	-	99.63	0.000
20-Jul-07	-	-	-	0.0001	-	-	-	-	0.595	-	99.659	0.000
21-Jul-07	-	-	-	0.0000	-	-	-	-	0.567	-	99.655	0.000
22-Jul-07	-	-	-	0.0000	-	-	-	-	0.538	-	99.653	0.000
23-Jul-07	-	-	-	0.0000	-	-	-	-	0.491	-	99.649	0.000
24-Jul-07	-	-	-	0.0000	-	-	-	-	0.490	-	99.65	0.000
25-Jul-07	-	-	-	0.0000	-	-	-	-	0.460	-	99.646	0.000
26-Jul-07	-	-	-	0.0000	-	-	-	-	0.464	-	99.648	0.000
27-Jul-07	-	-	-	0.0000	-	-	-	-	0.367	-	99.646	0.000
28-Jul-07	-	-	-	0.0000	-	-	-	-	0.386	-	99.645	0.020
29-Jul-07	-	-	-	0.0000	-	-	-	-	0.427	-	99.644	0.066
30-Jul-07	-	-	-	0.0000	-	-	-	-	0.335	-	99.64	0.098
31-Jul-07	-	-	-	0.0000	-	-	-	-	0.292	-	99.636	0.103
01-Aug-07	-	-	-	0.0000	-	-	-	-	0.258	-	99.642	0.111
02-Aug-07	-	-	-	0.0000	-	-	-	-	0.219	-	99.639	-
03-Aug-07	-	-	-	0.0000	-	-	-	-	0.228	-	99.638	-
04-Aug-07	-	-	-	0.0000	-	-	-	-	0.252	-	99.635	-
05-Aug-07	-	-	-	0.0000	-	-	-	-	0.278	-	99.635	-
06-Aug-07	-	-	-	0.0000	-	-	-	-	0.387	-	99.634	0.144
07-Aug-07	-	-	-	0.0000	-	-	-	-	0.396	-	99.633	-
08-Aug-07	-	-	-	0.0000	-	-	-	-	0.427	-	99.635	-
09-Aug-07	-	-	-	0.0000	-	-	-	-	0.439	-	99.633	-
10-Aug-07	-	-	-	0.0000	-	-	-	-	0.464	-	99.629	0.071
11-Aug-07	-	-	-	0.0000	-	-	-	-	0.501	-	99.618	0.063
12-Aug-07	-	-	-	0.0000	-	-	-	-	0.535	-	99.604	-
13-Aug-07	-	-	-	0.0000	-	-	-	-	0.569	-	99.592	-
14-Aug-07	-	-	-	0.0000	-	-	-	-	0.552	-	99.582	0.138
15-Aug-07	-	-	-	0.0000	-	-	-	-	0.528	-	99.578	0.123
16-Aug-07	-	-	-	0.0000	-	-	-	-	0.476	-	99.556	0.103
17-Aug-07	-	-	-	0.0000	-	-	-	-	0.443	-	99.534	0.087
18-Aug-07	-	-	-	0.0000	-	-	-	-	0.408	-	99.513	-
19-Aug-07	-	-	-	0.0000	-	-	-	-	0.404	-	99.502	-
20-Aug-07	-	-	-	0.0000	-	-	-	-	0.467	-	99.558	-
21-Aug-07	-	-	-	0.0001	-	0.061	-	-	0.521	-	99.622	-
22-Aug-07	-	-	-	325.0202	-	0.137	-	-	0.821	-	99.653	-
23-Aug-07	-	-	-	77.3886	-	0.110	-	-	1.033	-	99.656	-
24-Aug-07	-	-	-	23.1166	-	0.079	-	-	1.128	-	99.657	-
25-Aug-07	-	-	-	21.7023	-	0.068	-	-	1.189	-	99.655	0.053
26-Aug-07	-	-	-	11.2579	-	0.059	-	-	1.251	-	99.655	0.036
27-Aug-07	-	-	-	3.4476	-	-	-	-	1.244	-	99.657	0.019
28-Aug-07	-	-	-	0.8803	-	-	-	-	1.196	-	99.659	-
29-Aug-07	-	-	-	0.2133	-	-	-	-	1.115	-	99.659	-
30-Aug-07	-	-	-	0.4412	-	-	-	-	1.061	-	99.659	-
31-Aug-07	-	-	-	7.6744	-	0.059	-	-	1.186	-	99.673	-
01-Sep-07	-	-	-	5.8585	-	0.053	-	-	1.177	-	99.674	-
02-Sep-07	-	-	-	2.7656	-	-	-	-	1.182	-	99.674	-
03-Sep-07	-	-	-	0.7254	-	-	-	-	1.219	-	99.672	0.015
04-Sep-07	-	-	-	0.3030	-	-	-	-	1.239	-	99.673	-
05-Sep-07	-	-	-	0.2879	-	-	-	-	1.253	-	99.674	-
06-Sep-07	-	-	-	0.1384	-	-	-	-	1.219	-	99.672	-
07-Sep-07	-	-	-	0.0801	-	-	-	-	1.189	-	99.672	-
08-Sep-07	-	-	-	0.0543	-	-	-	-	1.166	-	99.672	-
09-Sep-07	-	-	-	0.0319	-	-	-	-	1.133	-	99.671	-
10-Sep-07	-	-	-	0.0279	-	-	-	-	1.090	-	99.673	-
11-Sep-07	-	-	-	-	-	0.102	-	-	1.266	-	99.68032832	-
12-Sep-07	-	-	-	-	-	0.137	-	-	1.368	-	99.68343283	-
13-Sep-07	-	-	-	-	-	0.142	-	-	1.445	-	99.68476217	-
14-Sep-07	-	-	-	-	-	0.124	-	-	1.528	-	99.68320825	-
15-Sep-07	-	-	-	-	-	0.107	-	-	1.562	-	99.68945213	-
16-Sep-07	-	-	-	-	-	0.096	-	-	1.544	-	99.70242354	-
17-Sep-07	-	-	-	-	-	0.096	-	-	1.545	-	99.70590628	-
18-Sep-07	-	-	-	-	-	0.094	-	-	1.547	-	99.71937602	-
19-Sep-07	-	-	-	-	-	0.097	-	-	1.494	-	99.71056249	-
20-Sep-07	-	-	-	-	-	0.097	-	-	1.480	-	99.69376298	-
21-Sep-07	-	-	-	-	-	0.116	-	-	1.491	-	99.70705858	0.000

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
22-Sep-07	-	-	-	-	-	0.124	-	-	1.481	-	99.70059252	-
23-Sep-07	-	-	-	-	-	0.118	-	-	1.466	-	99.71998374	-
24-Sep-07	-	-	-	-	-	0.108	-	-	1.235	-	99.72485925	-
25-Sep-07	-	-	-	-	-	0.120	-	-	1.231	-	99.70424067	-
26-Sep-07	-	-	-	-	-	0.110	-	-	1.247	-	99.70488207	-
27-Sep-07	-	-	-	-	-	0.111	-	-	1.252	-	99.71977533	-
28-Sep-07	-	-	-	-	-	0.101	-	-	1.235	-	99.71905829	-
29-Sep-07	-	-	-	-	-	0.085	-	-	1.184	-	99.72336608	0.000
30-Sep-07	-	-	-	-	-	0.077	-	-	1.123	-	99.7231906	0.000
01-Oct-07	-	-	-	0.1761	-	0.072	-	-	1.083	-	99.72159672	0.000
02-Oct-07	-	-	-	0.1130	-	0.066	-	-	1.048	-	99.72320335	0.000
03-Oct-07	-	-	-	0.0767	-	0.064	-	-	1.009	-	99.72314832	0.000
04-Oct-07	-	-	-	0.0628	-	0.062	-	-	0.953	-	99.73324516	0.000
05-Oct-07	-	-	-	0.0347	-	0.060	-	-	0.903	-	99.73850197	-
06-Oct-07	-	-	-	0.0286	-	0.059	-	-	0.871	-	99.72345929	-
07-Oct-07	-	-	-	0.0238	-	0.056	-	-	0.841	-	99.72447388	-
08-Oct-07	-	-	-	0.0199	-	0.053	-	-	0.811	-	99.73156466	-
09-Oct-07	-	-	-	0.0163	-	0.049	-	-	0.771	-	99.74074513	-
10-Oct-07	-	-	-	0.0610	-	0.048	-	-	0.739	-	99.72807207	-
11-Oct-07	-	-	-	0.0511	-	0.049	-	-	0.707	-	99.73305086	-
12-Oct-07	-	-	-	0.0108	-	-	-	-	0.677	-	99.73474909	-
13-Oct-07	-	-	-	0.0090	-	-	-	-	0.651	-	99.73623972	-
14-Oct-07	-	-	-	0.0076	-	-	-	-	0.630	-	99.7335768	-
15-Oct-07	-	-	-	0.0062	-	-	-	-	0.609	-	99.74089008	-
16-Oct-07	-	-	-	-	-	-	-	-	0.588	-	99.74035792	-
17-Oct-07	-	-	-	-	-	-	-	-	0.562	-	99.74168843	-
29-Apr-08	-	-	-	0.120	-	-	-	13.780	-	-	-	-
30-Apr-08	-	-	-	0.159	-	-	-	17.107	-	-	-	-
01-May-08	-	-	-	0.141	-	-	-	19.996	-	-	-	-
02-May-08	-	-	-	0.123	-	-	-	23.000	-	-	-	-
03-May-08	-	-	-	0.119	-	-	-	26.249	-	-	-	-
04-May-08	-	-	-	0.121	-	-	-	21.174	-	-	-	-
05-May-08	-	-	-	0.122	-	-	-	16.963	-	-	-	-
06-May-08	-	-	-	0.121	-	-	-	13.440	-	-	-	-
07-May-08	-	-	-	0.115	-	-	-	10.161	-	-	-	-
08-May-08	-	-	-	0.104	-	-	-	-	-	-	-	-
09-May-08	-	-	-	0.094	-	-	-	-	-	-	-	-
10-May-08	-	-	-	0.086	-	-	-	-	-	-	-	-
11-May-08	-	-	-	0.083	-	-	-	-	-	-	-	-
12-May-08	-	-	-	0.082	-	-	-	-	-	-	-	-
13-May-08	-	-	-	0.075	-	-	-	-	-	-	-	-
14-May-08	-	-	-	0.079	-	-	-	-	-	-	-	-
15-May-08	-	-	-	0.079	-	-	-	-	-	-	-	-
16-May-08	-	-	-	0.076	-	-	-	-	-	-	-	-
17-May-08	-	-	-	0.070	-	-	-	-	-	-	-	-
18-May-08	-	-	-	0.066	-	-	-	-	-	-	-	-
19-May-08	-	-	-	0.060	-	-	-	-	-	-	-	-
20-May-08	-	-	-	0.051	-	-	-	-	-	-	-	-
21-May-08	-	-	-	0.047	-	-	-	-	-	-	-	-
22-May-08	-	-	-	0.044	-	-	-	-	-	-	-	-
23-May-08	-	-	-	0.041	-	-	-	-	-	-	-	-
24-May-08	-	-	-	0.038	-	-	-	-	-	-	-	-
06-Jul-08	-	-	-	0.009	-	-	-	7.816	-	-	-	-
07-Jul-08	-	-	-	0.007	-	0.045	-	7.880	-	-	99.645	-
08-Jul-08	-	-	-	0.006	-	0.034	-	7.568	-	-	99.643	-
09-Jul-08	-	-	-	-	-	0.038	-	7.309	-	-	99.642	-
10-Jul-08	-	-	-	0.004	-	0.040	-	6.985	-	-	99.64	-
11-Jul-08	-	-	-	-	-	0.037	-	6.783	-	-	99.631	-
12-Jul-08	-	-	-	0.004	-	0.036	-	6.649	-	-	99.627	-
13-Jul-08	-	-	-	-	-	0.066	-	7.756	-	-	99.639	-
14-Jul-08	-	-	-	-	-	0.065	-	8.715	-	-	99.64	-
15-Jul-08	-	-	-	-	-	0.065	-	8.927	-	-	99.636	-
16-Jul-08	-	-	-	-	-	0.057	-	9.009	-	-	99.632	-
17-Jul-08	-	-	-	-	-	0.053	-	8.973	-	-	99.625	-
18-Jul-08	-	-	-	-	-	0.051	-	8.682	-	-	99.62	-
19-Jul-08	-	-	-	-	-	0.047	-	8.121	-	-	99.617	-
20-Jul-08	-	-	-	-	-	0.041	-	7.777	-	-	99.613	-
21-Jul-08	-	-	-	-	-	0.034	-	7.273	-	-	99.609	-
22-Jul-08	-	-	-	-	-	0.025	-	6.723	-	-	99.605	-
23-Jul-08	-	-	-	-	-	0.020	-	6.448	-	-	99.601	-
24-Jul-08	-	-	-	-	-	0.011	-	6.226	-	-	99.596	-
25-Jul-08	-	-	-	-	-	0.007	-	5.767	-	-	99.591	-
26-Jul-08	-	-	-	-	-	0.004	-	5.225	-	-	99.587	-
27-Jul-08	-	-	-	-	-	0.049	-	6.004	-	-	99.581	-
28-Jul-08	-	-	-	-	-	0.127	-	8.415	-	-	99.608	-
29-Jul-08	-	-	-	-	-	0.091	-	9.603	-	-	99.675	-
30-Jul-08	-	-	-	-	-	0.065	-	9.544	-	-	99.696	-
31-Jul-08	-	-	-	-	-	0.048	-	9.472	-	-	99.699	-
01-Aug-08	-	-	-	-	-	0.045	-	9.534	-	-	99.703	-
02-Aug-08	-	-	-	-	-	0.092	-	11.681	-	-	-	-
03-Aug-08	-	-	-	-	-	0.158	-	17.192	-	-	-	-
04-Aug-08	-	-	-	-	-	0.155	-	20.304	-	-	-	-
05-Aug-08	-	-	-	-	-	0.147	-	22.616	-	-	-	-
06-Aug-08	-	-	-	-	-	0.132	-	23.218	-	-	99.722	-
07-Aug-08	-	-	-	-	-	0.116	-	22.875	-	-	-	-
08-Aug-08	-	-	-	-	-	0.105	-	22.087	-	-	-	-
09-Aug-08	-	-	-	-	-	0.086	-	20.864	-	-	-	-
10-Aug-08	-	-	-	-	-	0.077	-	19.404	-	-	99.685	-
11-Aug-08	-	-	-	-	-	0.072	-	18.400	-	-	99.681	-
12-Aug-08	-	-	-	-	-	0.072	-	19.411	-	-	-	-
13-Aug-08	-	-	-	-	-	-	-	24.273	-	-	-	-
14-Aug-08	-	-	-	-	-	-	-	27.213	-	-	99.721	-
15-Aug-08	-	-	-	-	-	-	-	28.661	-	-	99.713	-
16-Aug-08	-	-	-	-	-	-	-	28.683	-	-	99.703	-
17-Aug-08	-	-	-	-	-	-	-	27.714	-	-	99.695	-
18-Aug-08	-	-	-	-	-	-	-	26.312	-	-	-	-
19-Aug-08	-	-	-	-	-	-	-	24.667	-	-	-	-
20-Aug-08	-	-	-	-	-	-	-	24.149	-	-	-	-
21-Aug-08	-	-	-	-	-	-	-	23.282	-	-	-	-
22-Aug-08	-	-	-	-	-	-	-	22.096	-	-	-	-
23-Aug-08	-	-	-	-	-	-	-	21.378	-	-	-	-
24-Aug-08	-	-	-	-	-	-	-	20.078	-	-	-	-
25-Aug-08	-	-	-	-	-	-	-	18.604	-	-	99.679	-
26-Aug-08	-	-	-	-	-	-	-	16.774	-	-	99.671	-
27-Aug-08	-	-	-	-	-	-	-	15.473	-	-	99.663	-
28-Aug-08	-	-	-	-	-	-	-	14.357	-	-	-	-
29-Aug-08	-	-	-	-	-	-	-	13.505	-	-	-	-
30-Aug-08	-	-	-	-	-	-	-	13.317	-	-	-	-
31-Aug-08	-	-	-	-	-	-	-	13.005	-	-	-	-
01-Sep-08	-	-	-	-	-	-	-	12.443	-	-	-	-
02-Sep-08	-	-	-	-	-	-	-	11.898	-	-	-	-
03-Sep-08	-	-	-	-	-	-	-	11.423	-	-	99.662	-
04-Sep-08	-	-	-	-	-	-	-	10.861	-	-	-	-
05-Sep-08	-	-	-	-	-	-	-	10.362	-	-	-	-
06-Sep-08	-	-	-	-	-	-	-	9.829	-	-	-	-
07-Sep-08	-	-	-	-	-	-	-	9.298	-	-	-	-
08-Sep-08	-	-	-	-	-	-	-	8.786	-	-	-	-
09-Sep-08	-	-	-	-	-	-	-	8.747	-	-	-	-
10-Sep-08	-	-	-	-	-	-	-	8.505	-	-	-	-
11-Sep-08	-	-	-	-	-	-	-	8.484	-	-	-	-
12-Sep-08	-	-	-	-	-	-	-	8.300	-	-	-	-
13-Sep-08	-	-	-	-	-	-	-	8.035	-	-	-	-
14-Sep-08	-	-	-	-	-	-	-	7.937	-	-	-	-
15-Sep-08	-	-	-	-	-	-	-	7.790	-	-	-	-
16-Sep-08	-	-	-	-	-	-	-	7.391	-	-	-	-
17-Sep-08	-	-	-	-	-	-	-	7.367	-	-	-	-
18-Sep-08	-	-	-	-	-	-	-	7.627	-	-	-	-
19-Sep-08	-	-	-	-	-	-	-	7.465	-	-	-	-
20-Sep-08	-	-	-	-	-	-	-	7.406	-	-	-	-
21-Sep-08	-	-	-	-	-	-	-	7.184	-	-	99.605	-
22-Sep-08	-	-	-	-	-	-	-	7.134	-	-	-	-
23-Sep-08	-	-	-	-	-	-	-	7.920	-	-	-	-
24-Sep-08	-	-	-	-	-	-	-	8.893	-	-	-	-
25-Sep-08	-	-	-	-	-	-	-	9.705	-	-	-	-
26-Sep-08	-	-	-	-	-	-	-	10.431	-	-	-	-
27-Sep-08	-	-	-	-	-	-	-	11.689	-	-	-	-
28-Sep-08	-	-	-	-	-	-	-	11.819	-	-	-	-
29-Sep-08	-	-	-	-	-	-	-	11.789	-	-	99.643	-
30-Sep-08	-	-	-	-	-	-	-	11.704	-	-	99.64	-
01-Oct-08	-	-	-	-	-	-	-	11.509	-	-	99.638	-
02-Oct-08	-	-	-	-	-	-	-	11.396	-	-	99.637	-
03-Oct-08	-	-	-	-	-	-	-	11.210	-	-	99.631	-
04-Oct-08	-	-	-	-	-	-	-	10.989	-	-	99.627	-
05-Oct-08	-	-	-	-	-	-	-	10.995	-	-	-	-
06-Oct-08	-	-	-	-	-	-	-	11.951	-	-	-	-
07-Oct-08	-	-	-	-	-	-	-	12.958	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
08-Oct-08	-	-	-	-	-	-	-	13.353	-	-	-	-
09-Oct-08	-	-	-	-	-	-	-	13.648	-	-	-	-
10-Oct-08	-	-	-	-	-	-	-	13.685	-	-	-	-
11-Oct-08	-	-	-	-	-	-	-	13.485	-	-	-	-
12-Oct-08	-	-	-	-	-	-	-	13.311	-	-	-	-
13-Oct-08	-	-	-	-	-	-	-	12.985	-	-	-	-
14-Oct-08	-	-	-	-	-	-	-	12.685	-	-	-	-
15-Oct-08	-	-	-	-	-	-	-	12.434	-	-	-	-
16-Oct-08	-	-	-	-	-	-	-	12.257	-	-	-	-
17-Oct-08	-	-	-	-	-	-	-	12.178	-	-	-	-
18-Oct-08	-	-	-	-	-	-	-	11.983	-	-	-	-
19-Oct-08	-	-	-	-	-	-	-	11.803	-	-	-	-
20-Oct-08	-	-	-	-	-	-	-	11.642	-	-	-	-
21-Oct-08	-	-	-	-	-	-	-	11.527	-	-	-	-
22-Oct-08	-	-	-	-	-	-	-	11.093	-	-	-	-
19-Jul-09	-	-	-	0.026	-	-	-	-	-	-	-	-
20-Jul-09	-	-	-	0.026	-	0.087	-	-	-	-	-	-
21-Jul-09	-	-	-	0.022	-	0.081	-	-	-	-	-	-
22-Jul-09	-	-	-	0.021	-	0.076	-	-	-	-	-	-
23-Jul-09	-	-	-	0.032	-	0.079	-	-	-	-	-	-
24-Jul-09	-	-	-	0.035	-	0.078	-	-	-	-	-	-
25-Jul-09	-	-	-	0.032	-	0.079	-	-	-	-	-	-
26-Jul-09	-	-	-	0.028	-	0.074	-	-	-	-	-	-
27-Jul-09	-	-	-	0.026	-	0.070	-	-	-	-	-	-
28-Jul-09	-	-	-	0.026	-	0.069	-	-	-	-	-	-
29-Jul-09	-	-	-	0.023	-	0.064	-	-	-	-	-	-
30-Jul-09	-	-	-	0.022	-	0.059	-	-	-	-	-	-
31-Jul-09	-	-	-	0.020	-	0.052	-	-	-	-	-	-
01-Aug-09	-	-	-	0.020	-	0.042	-	-	-	-	-	-
02-Aug-09	-	-	-	0.020	-	0.044	-	-	-	-	-	-
03-Aug-09	-	-	-	0.020	-	0.042	-	-	-	-	-	-
04-Aug-09	-	-	-	0.022	-	0.043	-	-	-	-	-	-
05-Aug-09	-	-	-	0.026	-	0.043	-	-	-	-	-	-
06-Aug-09	-	-	-	0.025	-	0.032	-	-	-	-	-	-
07-Aug-09	-	-	-	0.022	-	0.029	-	-	-	-	-	-
08-Aug-09	-	-	-	0.022	-	0.026	-	-	-	-	-	-
09-Aug-09	-	-	-	0.020	-	0.025	-	-	-	-	-	-
10-Aug-09	-	-	-	0.020	-	0.023	-	-	-	-	-	-
11-Aug-09	-	-	-	0.019	-	0.020	-	-	-	-	-	-
12-Aug-09	-	-	-	0.016	-	0.028	-	-	-	-	-	-
13-Aug-09	-	-	-	0.017	-	0.031	-	-	-	-	-	-
14-Aug-09	-	-	-	0.020	-	0.025	-	-	-	-	-	-
15-Aug-09	-	-	-	0.017	-	0.025	-	-	-	-	-	-
16-Aug-09	-	-	-	0.013	-	0.021	-	-	-	-	-	-
17-Aug-09	-	-	-	0.009	-	0.023	-	-	-	-	-	-
18-Aug-09	-	-	-	0.008	-	0.022	-	-	-	-	-	-
19-Aug-09	-	-	-	0.009	-	0.022	-	-	-	-	-	-
20-Aug-09	-	-	-	0.012	-	0.023	-	-	-	-	-	-
21-Aug-09	-	-	-	0.010	-	0.020	-	-	-	-	-	-
22-Aug-09	-	-	-	0.014	-	0.030	-	-	-	-	-	-
23-Aug-09	-	-	-	0.026	-	0.035	-	-	-	-	-	-
24-Aug-09	-	-	-	0.116	-	0.115	-	-	-	-	-	-
25-Aug-09	-	-	-	0.145	-	0.123	-	-	-	-	-	-
26-Aug-09	-	-	-	0.115	-	0.119	-	-	-	-	-	-
27-Aug-09	-	-	-	0.092	-	0.114	-	-	-	-	-	-
28-Aug-09	-	-	-	0.074	-	0.105	-	-	-	-	-	-
29-Aug-09	-	-	-	0.061	-	0.095	-	-	-	-	-	-
30-Aug-09	-	-	-	0.050	-	0.086	-	-	-	-	-	-
31-Aug-09	-	-	-	0.043	-	0.078	-	-	-	-	-	-
01-Sep-09	-	-	-	0.037	-	0.071	-	-	-	-	-	-
02-Sep-09	-	-	-	0.035	-	0.064	-	-	-	-	-	-
03-Sep-09	-	-	-	0.034	-	0.057	-	-	-	-	-	-
04-Sep-09	-	-	-	0.032	-	0.055	-	-	-	-	-	-
05-Sep-09	-	-	-	0.030	-	0.055	-	-	-	-	-	-
06-Sep-09	-	-	-	0.029	-	0.053	-	-	-	-	-	-
07-Sep-09	-	-	-	0.029	-	0.054	-	-	-	-	-	-
08-Sep-09	-	-	-	0.030	-	0.056	-	-	-	-	-	-
09-Sep-09	-	-	-	0.033	-	0.071	-	-	-	-	-	-
10-Sep-09	-	-	-	0.029	-	0.067	-	-	-	-	-	-
11-Sep-09	-	-	-	0.027	-	0.063	-	-	-	-	-	-
12-Sep-09	-	-	-	0.024	-	0.061	-	-	-	-	-	-
13-Sep-09	-	-	-	0.022	-	0.057	-	-	-	-	-	-
14-Sep-09	-	-	-	0.020	-	0.045	-	-	-	-	-	-
15-Sep-09	-	-	-	0.019	-	0.048	-	-	-	-	-	-
16-Sep-09	-	-	-	0.017	-	0.051	-	-	-	-	-	-
17-Sep-09	-	-	-	0.018	-	0.051	-	-	-	-	-	-
18-Sep-09	-	-	-	0.018	-	0.057	-	-	-	-	-	-
19-Sep-09	-	-	-	0.016	-	0.053	-	-	-	-	-	-
20-Sep-09	-	-	-	0.015	-	0.052	-	-	-	-	-	-
21-Sep-09	-	-	-	0.015	-	0.057	-	-	-	-	-	-
22-Sep-09	-	-	-	0.014	-	0.059	-	-	-	-	-	-
23-Sep-09	-	-	-	0.013	-	0.057	-	-	-	-	-	-
24-Sep-09	-	-	-	0.012	-	0.056	-	-	-	-	-	-
25-Sep-09	-	-	-	0.011	-	0.051	-	-	-	-	-	-
26-Sep-09	-	-	-	0.013	-	0.063	-	-	-	-	-	-
27-Sep-09	-	-	-	0.014	-	0.067	-	-	-	-	-	-
28-Sep-09	-	-	-	0.016	-	0.065	-	-	-	-	-	-
29-Sep-09	-	-	-	0.016	-	0.064	-	-	-	-	-	-
30-Sep-09	-	-	-	0.017	-	0.065	-	-	-	-	-	-
01-Oct-09	-	-	-	0.016	-	0.064	-	-	-	-	-	-
02-Oct-09	-	-	-	0.014	-	0.061	-	-	-	-	-	-
03-Oct-09	-	-	-	0.014	-	0.065	-	-	-	-	-	-
04-Oct-09	-	-	-	0.014	-	0.071	-	-	-	-	-	-
05-Oct-09	-	-	-	0.015	-	0.065	-	-	-	-	-	-
06-Oct-09	-	-	-	0.016	-	0.066	-	-	-	-	-	-
07-Oct-09	-	-	-	0.016	-	0.065	-	-	-	-	-	-
08-Oct-09	-	-	-	0.016	-	0.063	-	-	-	-	-	-
09-Oct-09	-	-	-	0.014	-	0.064	-	-	-	-	-	-
10-Oct-09	-	-	-	0.014	-	0.065	-	-	-	-	-	-
11-Oct-09	-	-	-	0.014	-	0.065	-	-	-	-	-	-
12-Oct-09	-	-	-	0.014	-	0.065	-	-	-	-	-	-
13-Oct-09	-	-	-	0.014	-	0.066	-	-	-	-	-	-
14-Oct-09	-	-	-	0.013	-	0.070	-	-	-	-	-	-
15-Oct-09	-	-	-	0.014	-	0.062	-	-	-	-	-	-
16-Oct-09	-	-	-	0.015	-	0.063	-	-	-	-	-	-
17-Oct-09	-	-	-	0.019	-	0.071	-	-	-	-	-	-
18-Oct-09	-	-	-	0.021	-	0.071	-	-	-	-	-	-
19-Oct-09	-	-	-	0.019	-	0.070	-	-	-	-	-	-
20-Oct-09	-	-	-	0.019	-	0.072	-	-	-	-	-	-
21-Oct-09	-	-	-	0.018	-	0.071	-	-	-	-	-	-
22-Oct-09	-	-	-	0.018	-	0.075	-	-	-	-	-	-
23-Oct-09	-	-	-	0.020	-	0.079	-	-	-	-	-	-
24-Oct-09	-	-	-	0.021	-	-	-	-	-	-	-	-
06-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
07-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
08-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
09-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
10-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
11-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
12-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
13-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
14-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
15-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
16-Jan-10	-	-	-	-	-	-	97.241	28.742	-	-	-	-
17-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
18-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
19-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
20-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
21-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
22-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
23-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
24-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
25-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
26-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
27-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
28-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
29-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
30-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
31-Jan-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
01-Feb-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
02-Feb-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
03-Feb-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
04-Feb-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
05-Feb-10	-	-	-	-	-	-	97.241	28.741	-	-	-	-
06-Feb-10	-	-	-	-	-	-	97.229	27.810	-	-	-	-
07-Feb-10	-	-	-	-	-	-	97.229	27.819	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
08-Feb-10	-	-	-	-	-	-	97.229	27.828	-	-	-	-
09-Feb-10	-	-	-	-	-	-	97.229	27.837	-	-	-	-
10-Feb-10	-	-	-	-	-	-	97.229	27.846	-	-	-	-
11-Feb-10	-	-	-	-	-	-	97.229	27.855	-	-	-	-
12-Feb-10	-	-	-	-	-	-	97.229	27.864	-	-	-	-
13-Feb-10	-	-	-	-	-	-	97.229	27.873	-	-	-	-
14-Feb-10	-	-	-	-	-	-	97.229	27.882	-	-	-	-
15-Feb-10	-	-	-	-	-	-	97.230	27.890	-	-	-	-
16-Feb-10	-	-	-	-	-	-	97.230	27.899	-	-	-	-
17-Feb-10	-	-	-	-	-	-	97.230	27.908	-	-	-	-
18-Feb-10	-	-	-	-	-	-	97.230	27.917	-	-	-	-
19-Feb-10	-	-	-	-	-	-	97.230	27.926	-	-	-	-
20-Feb-10	-	-	-	-	-	-	97.230	27.935	-	-	-	-
21-Feb-10	-	-	-	-	-	-	97.230	27.944	-	-	-	-
22-Feb-10	-	-	-	-	-	-	97.230	27.953	-	-	-	-
23-Feb-10	-	-	-	-	-	-	97.231	27.962	-	-	-	-
24-Feb-10	-	-	-	-	-	-	97.231	27.971	-	-	-	-
25-Feb-10	-	-	-	-	-	-	97.231	27.980	-	-	-	-
26-Feb-10	-	-	-	-	-	-	97.231	27.989	-	-	-	-
27-Feb-10	-	-	-	-	-	-	97.231	27.998	-	-	-	-
28-Feb-10	-	-	-	-	-	-	97.231	28.007	-	-	-	-
01-Mar-10	-	-	-	-	-	-	97.231	28.015	-	-	-	-
02-Mar-10	-	-	-	-	-	-	97.231	28.024	-	-	-	-
03-Mar-10	-	-	-	-	-	-	97.232	28.033	-	-	-	-
04-Mar-10	-	-	-	-	-	-	97.232	28.042	-	-	-	-
05-Mar-10	-	-	-	-	-	-	97.232	28.051	-	-	-	-
06-Mar-10	-	-	-	-	-	-	97.225	27.535	-	-	-	-
07-Mar-10	-	-	-	-	-	-	97.225	27.530	-	-	-	-
08-Mar-10	-	-	-	-	-	-	97.225	27.526	-	-	-	-
09-Mar-10	-	-	-	-	-	-	97.225	27.522	-	-	-	-
10-Mar-10	-	-	-	-	-	-	97.225	27.517	-	-	-	-
11-Mar-10	-	-	-	-	-	-	97.224	27.513	-	-	-	-
12-Mar-10	-	-	-	-	-	-	97.224	27.508	-	-	-	-
13-Mar-10	-	-	-	-	-	-	97.224	27.504	-	-	-	-
14-Mar-10	-	-	-	-	-	-	97.224	27.500	-	-	-	-
15-Mar-10	-	-	-	-	-	-	97.224	27.495	-	-	-	-
16-Mar-10	-	-	-	-	-	-	97.224	27.491	-	-	-	-
17-Mar-10	-	-	-	-	-	-	97.224	27.486	-	-	-	-
18-Mar-10	-	-	-	-	-	-	97.224	27.482	-	-	-	-
19-Mar-10	-	-	-	-	-	-	97.224	27.478	-	-	-	-
20-Mar-10	-	-	-	-	-	-	97.224	27.473	-	-	-	-
21-Mar-10	-	-	-	-	-	-	97.224	27.469	-	-	-	-
22-Mar-10	-	-	-	-	-	-	97.224	27.464	-	-	-	-
23-Mar-10	-	-	-	-	-	-	97.224	27.460	-	-	-	-
24-Mar-10	-	-	-	-	-	-	97.224	27.456	-	-	-	-
25-Mar-10	-	-	-	-	-	-	97.224	27.451	-	-	-	-
26-Mar-10	-	-	-	-	-	-	97.224	27.447	-	-	-	-
27-Mar-10	-	-	-	-	-	-	97.224	27.442	-	-	-	-
28-Mar-10	-	-	-	-	-	-	97.223	27.438	-	-	-	-
29-Mar-10	-	-	-	-	-	-	97.223	27.434	-	-	-	-
30-Mar-10	-	-	-	-	-	-	97.223	27.429	-	-	-	-
31-Mar-10	-	-	-	-	-	-	97.223	27.425	-	-	-	-
01-Apr-10	-	-	-	-	-	-	97.223	27.420	-	-	-	-
02-Apr-10	-	-	-	-	-	-	97.223	27.416	-	-	-	-
03-Apr-10	-	-	-	-	-	-	97.223	27.412	-	-	-	-
04-Apr-10	-	-	-	-	-	-	97.223	27.407	-	-	-	-
05-Apr-10	-	-	-	-	-	-	97.223	27.403	-	-	-	-
06-Apr-10	-	-	-	-	-	-	97.214	26.776	-	-	-	-
07-Apr-10	-	-	-	-	-	-	97.214	26.811	-	-	-	-
08-Apr-10	-	-	-	-	-	-	97.214	26.847	-	-	-	-
09-Apr-10	-	-	-	-	-	-	97.214	26.882	-	-	-	-
10-Apr-10	-	-	-	-	-	-	97.214	26.917	-	-	-	-
11-Apr-10	-	-	-	-	-	-	97.214	26.953	-	-	-	-
12-Apr-10	-	-	-	-	-	-	97.214	26.988	-	-	-	-
13-Apr-10	-	-	-	-	-	-	97.214	27.024	-	-	-	-
14-Apr-10	-	-	-	-	-	-	97.214	27.059	-	-	-	-
15-Apr-10	-	-	-	-	-	-	97.214	27.094	-	-	-	-
16-Apr-10	-	-	-	-	-	-	97.214	27.130	-	-	-	-
17-Apr-10	-	-	-	-	-	-	97.214	27.165	-	-	-	-
18-Apr-10	-	-	-	-	-	-	97.214	27.200	-	-	-	-
19-Apr-10	-	-	-	-	-	-	97.214	27.236	-	-	-	-
20-Apr-10	-	-	-	-	-	-	97.214	27.271	-	-	-	-
21-Apr-10	-	-	-	-	-	-	97.214	27.307	-	-	-	-
22-Apr-10	-	-	-	-	-	-	97.214	27.342	-	-	-	-
23-Apr-10	-	-	-	-	-	-	97.214	27.377	-	-	-	-
24-Apr-10	-	-	-	-	-	-	97.214	27.413	-	-	-	-
25-Apr-10	-	-	-	-	-	-	97.214	27.448	-	-	-	-
26-Apr-10	-	-	-	-	-	-	97.214	27.483	-	-	-	-
27-Apr-10	-	-	-	0.071	-	-	97.214	27.519	-	-	-	-
28-Apr-10	-	-	-	0.070	-	0.102	97.214	27.554	-	-	-	-
29-Apr-10	-	-	-	0.082	-	0.098	97.214	27.589	-	2.279	-	-
30-Apr-10	-	-	-	0.086	-	0.100	97.214	27.625	-	2.702	-	-
01-May-10	-	-	-	0.094	-	0.108	97.214	27.660	-	3.231	-	-
02-May-10	-	-	-	0.092	-	0.119	97.214	27.696	-	3.331	-	-
03-May-10	-	-	-	0.091	-	0.074	97.214	27.731	-	3.362	-	-
04-May-10	-	-	-	0.089	-	0.114	97.214	27.766	-	3.362	-	-
05-May-10	-	-	-	0.086	-	0.091	97.214	27.802	-	3.356	-	-
06-May-10	-	-	-	0.084	-	0.089	97.199	26.687	-	3.354	-	-
07-May-10	-	-	-	0.082	-	0.064	97.199	26.683	-	3.348	-	-
08-May-10	-	-	-	0.079	-	0.067	97.199	26.679	-	3.332	-	-
09-May-10	-	-	-	0.077	-	0.104	97.199	26.676	-	3.300	-	-
10-May-10	-	-	-	0.076	-	0.076	97.199	26.672	-	3.244	-	-
11-May-10	-	-	-	0.074	-	0.086	97.199	26.668	-	3.173	-	-
12-May-10	-	-	-	0.074	-	0.076	97.199	26.664	-	3.092	-	-
13-May-10	-	-	-	0.072	-	0.074	97.199	26.660	-	3.020	-	-
14-May-10	-	-	-	0.071	-	0.071	97.199	26.656	-	2.969	-	-
15-May-10	-	-	-	0.069	-	0.069	97.199	26.652	-	2.899	-	-
16-May-10	-	-	-	0.067	-	0.067	97.199	26.648	-	2.828	-	-
17-May-10	-	-	-	0.065	-	0.066	97.199	26.644	-	2.765	-	-
18-May-10	-	-	-	0.064	-	0.064	97.199	26.640	-	2.707	-	-
19-May-10	-	-	-	0.063	-	0.068	97.199	26.636	-	2.633	-	-
20-May-10	-	-	-	0.064	-	0.058	97.200	26.632	-	2.551	-	-
21-May-10	-	-	-	0.069	-	0.073	97.200	26.628	-	2.477	-	-
22-May-10	-	-	-	0.073	-	0.111	97.200	26.624	-	2.406	-	-
23-May-10	-	-	-	0.071	-	0.121	97.200	26.620	-	2.307	-	-
24-May-10	-	-	-	0.069	-	0.081	97.200	26.616	-	2.183	-	-
25-May-10	-	-	-	0.067	-	0.082	97.200	26.612	-	2.065	-	-
26-May-10	-	-	-	0.064	-	0.081	97.200	26.608	-	1.928	-	-
27-May-10	-	-	-	0.060	-	0.084	97.200	26.604	-	1.763	-	-
28-May-10	-	-	-	0.057	-	0.085	97.200	26.600	-	1.626	-	-
29-May-10	-	-	-	0.054	-	0.080	97.200	26.596	-	1.472	-	-
30-May-10	-	-	-	0.052	-	0.065	97.200	26.592	-	1.358	-	-
31-May-10	-	-	-	0.050	-	0.065	97.200	26.588	-	1.270	-	-
01-Jun-10	-	-	-	0.047	-	0.060	97.200	26.584	-	1.180	-	-
02-Jun-10	-	-	-	0.045	-	0.063	97.200	26.580	-	1.085	-	-
03-Jun-10	-	-	-	0.042	-	0.055	97.200	26.576	-	1.006	-	-
04-Jun-10	-	-	-	0.040	-	0.060	97.200	26.572	-	0.937	-	-
05-Jun-10	-	-	-	0.038	-	0.055	97.200	26.568	-	0.879	-	-
06-Jun-10	-	-	-	0.045	-	0.071	97.185	25.448	-	0.896	-	-
07-Jun-10	-	-	-	0.043	-	0.125	97.185	25.443	-	0.856	-	-
08-Jun-10	-	-	-	0.040	-	0.077	97.185	25.439	-	0.800	-	-
09-Jun-10	-	-	-	0.038	-	0.063	97.185	25.435	-	0.777	-	-
10-Jun-10	-	-	-	0.036	-	0.064	97.185	25.431	-	0.797	-	-
11-Jun-10	-	-	-	0.033	-	0.062	97.185	25.427	-	0.760	-	-
12-Jun-10	-	-	-	0.031	-	0.066	97.185	25.423	-	0.744	-	-
13-Jun-10	-	-	-	0.029	-	0.057	97.185	25.419	-	0.726	-	-
14-Jun-10	-	-	-	0.028	-	0.063	97.185	25.415	-	0.762	-	-
15-Jun-10	-	-	-	0.027	-	0.057	97.185	25.411	-	0.748	-	-
16-Jun-10	-	-	-	0.024	-	0.055	97.185	25.407	-	0.728	-	-
17-Jun-10	-	-	-	0.022	-	0.050	97.185	25.402	-	0.718	-	-
18-Jun-10	-	-	-	0.020	-	0.048	97.185	25.398	-	0.659	-	-
19-Jun-10	-	-	-	0.018	-	0.047	97.185	25.394	-	0.614	-	-
20-Jun-10	-	-	-	0.017	-	0.053	97.185	25.390	-	0.553	-	-
21-Jun-10	-	-	-	0.015	-	0.037	97.185	25.386	-	0.499	-	-
22-Jun-10	-	-	-	0.014	-	0.035	97.185	25.382	-	0.446	-	-
23-Jun-10	-	-	-	0.013	-	0.032	97.185	25.378	-	0.499	-	-
24-Jun-10	-	-	-	0.008	-	0.031	97.185	25.374	-	0.599	-	-
25-Jun-10	-	-	-	0.004	-	0.032	97.185	25.370	-	0.578	-	-
26-Jun-10	-	-	-	0.003	-	0.043	97.185	25.366	-	0.564	-	-
27-Jun-10	-	-	-	0.003	-	0.046	97.185	25.361	-	0.576	-	-
28-Jun-10	-	-	-	0.005	-	0.049	97.185	25.357	-	0.532	-	-
29-Jun-10	-	-	-	0.007	-	0.056	97.186	25.353	-	0.476	-	-
30-Jun-10	-	-	-	0.008	-	0.056	97.186	25.349	-	0.409	-	-
01-Jul-10	-	-	-	0.012	-	0.054	97.186	25.345	-	0.350	-	-
02-Jul-10	-	-	-	0.011	-	0.049	97.186	25.341	-	0.289	-	-
03-Jul-10	-	-	-	0.010	-	0.043	97.186	25.337	-	0.241	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
04-Jul-10	-	-	-	0.010	-	0.041	97.186	25.333	-	0.231	-	-
05-Jul-10	-	-	-	0.010	-	0.038	97.186	25.329	-	0.248	-	-
06-Jul-10	-	-	-	0.011	-	0.034	97.172	24.328	-	0.228	-	-
07-Jul-10	-	-	-	0.010	-	0.029	97.172	24.315	-	0.187	-	-
08-Jul-10	-	-	-	0.009	-	0.029	97.171	24.301	-	0.182	-	-
09-Jul-10	-	-	-	0.009	-	0.032	97.171	24.287	-	0.168	-	-
10-Jul-10	-	-	-	0.008	-	0.032	97.171	24.273	-	0.164	-	-
11-Jul-10	-	-	-	0.007	-	0.026	97.171	24.259	-	0.166	-	-
12-Jul-10	-	-	-	0.007	-	0.026	97.171	24.245	-	0.145	-	-
13-Jul-10	-	-	-	0.008	-	0.026	97.171	24.232	-	0.186	-	-
14-Jul-10	-	-	-	0.006	-	0.024	97.171	24.218	-	0.201	-	-
15-Jul-10	-	-	-	0.005	-	0.022	97.171	24.204	-	0.213	-	-
16-Jul-10	-	-	-	0.005	-	0.020	97.171	24.190	-	0.235	-	-
17-Jul-10	-	-	-	0.004	-	0.018	97.171	24.176	-	0.294	-	-
18-Jul-10	-	-	-	0.004	-	0.018	97.171	24.162	-	0.320	-	-
19-Jul-10	-	-	-	0.003	-	0.014	97.171	24.149	-	0.329	-	-
20-Jul-10	-	-	-	0.003	-	0.012	97.171	24.135	-	0.313	-	-
21-Jul-10	-	-	-	0.003	-	0.007	97.171	24.121	-	0.291	-	-
22-Jul-10	-	-	-	0.002	-	0.003	97.171	24.107	-	0.260	-	-
23-Jul-10	-	-	-	0.002	-	0.002	97.171	24.093	-	0.303	-	-
24-Jul-10	-	-	-	0.002	-	0.002	97.171	24.079	-	0.290	-	-
25-Jul-10	-	-	-	0.001	-	0.001	97.170	24.065	-	0.306	-	-
26-Jul-10	-	-	-	0.001	-	0.010	97.170	24.052	-	0.330	-	-
27-Jul-10	-	-	-	0.001	-	0.020	97.170	24.038	-	0.496	-	-
28-Jul-10	-	-	-	0.000	-	0.014	97.170	24.024	-	0.747	-	-
29-Jul-10	-	-	-	0.000	-	0.010	97.170	24.010	-	0.666	-	-
30-Jul-10	-	-	-	0.000	-	0.008	97.170	23.996	-	0.598	-	-
31-Jul-10	-	-	-	0.006	-	0.008	97.170	23.982	-	0.568	-	-
01-Aug-10	-	-	-	0.003	-	0.008	97.170	23.969	-	0.577	-	-
02-Aug-10	-	-	-	0.004	-	0.018	97.170	23.955	-	0.798	-	-
03-Aug-10	-	-	-	0.010	-	0.036	97.170	23.941	-	1.115	-	-
04-Aug-10	-	-	-	0.006	-	0.036	97.170	23.927	-	1.118	-	-
05-Aug-10	-	-	-	0.004	-	0.040	97.170	23.913	-	1.327	-	-
06-Aug-10	-	-	-	0.002	-	0.034	97.156	22.934	-	1.579	-	-
07-Aug-10	-	-	-	0.006	-	0.039	97.156	22.915	-	1.575	-	-
08-Aug-10	-	-	-	0.003	-	0.033	97.156	22.897	-	1.518	-	-
09-Aug-10	-	-	-	0.001	-	0.028	97.156	22.878	-	1.353	-	-
10-Aug-10	-	-	-	0.000	-	0.022	97.156	22.859	-	1.167	-	-
11-Aug-10	-	-	-	0.000	-	0.017	97.156	22.840	-	1.007	-	-
12-Aug-10	-	-	-	0.000	-	0.014	97.156	22.822	-	1.026	-	-
13-Aug-10	-	-	-	0.000	-	0.027	97.156	22.803	-	1.315	-	-
14-Aug-10	-	-	-	0.000	-	0.035	97.156	22.784	-	1.614	-	-
15-Aug-10	-	-	-	0.000	-	0.031	97.156	22.765	-	2.087	-	-
16-Aug-10	-	-	-	0.000	-	0.030	97.156	22.747	-	2.439	-	-
17-Aug-10	-	-	-	0.000	-	0.027	97.156	22.728	-	2.499	-	-
18-Aug-10	-	-	-	0.000	-	0.024	97.156	22.709	-	2.412	-	-
19-Aug-10	-	-	-	0.000	-	0.021	97.156	22.690	-	2.269	-	-
20-Aug-10	-	-	-	0.000	-	0.022	97.156	22.671	-	2.320	-	-
21-Aug-10	-	-	-	0.000	-	0.020	97.156	22.653	-	2.208	-	-
22-Aug-10	-	-	-	0.000	-	0.018	97.156	22.634	-	2.035	-	-
23-Aug-10	-	-	-	0.002	-	0.017	97.156	22.615	-	1.953	-	-
24-Aug-10	-	-	-	0.004	-	0.016	97.156	22.596	-	1.834	-	-
25-Aug-10	-	-	-	0.004	-	0.018	97.156	22.578	-	1.658	-	-
26-Aug-10	-	-	-	0.005	-	0.021	97.156	22.559	-	1.436	-	-
27-Aug-10	-	-	-	0.008	-	0.061	97.156	22.540	-	1.250	-	-
28-Aug-10	-	-	-	0.012	-	0.093	97.156	22.521	-	1.105	-	-
29-Aug-10	-	-	-	0.012	-	0.095	97.156	22.503	-	1.006	-	-
30-Aug-10	-	-	-	0.011	-	0.092	97.156	22.484	-	1.014	-	-
31-Aug-10	-	-	-	0.010	-	0.104	97.156	22.465	-	1.012	-	-
01-Sep-10	-	-	-	0.011	-	0.107	97.156	22.446	-	0.930	-	-
02-Sep-10	-	-	-	0.010	-	0.097	97.156	22.428	-	0.889	-	-
03-Sep-10	-	-	-	0.009	-	0.082	97.157	22.409	-	0.850	-	-
04-Sep-10	-	-	-	0.009	-	0.073	97.157	22.390	-	0.819	-	-
05-Sep-10	-	-	-	0.012	-	0.108	97.157	22.371	-	0.775	-	-
06-Sep-10	-	-	-	0.019	-	0.151	97.142	21.406	-	0.722	-	-
07-Sep-10	-	-	-	0.016	-	0.147	97.142	21.385	-	0.671	-	-
08-Sep-10	-	-	-	0.014	-	0.143	97.142	21.364	-	0.626	-	-
09-Sep-10	-	-	-	0.013	-	0.133	97.142	21.343	-	0.621	-	-
10-Sep-10	-	-	-	0.012	-	0.126	97.142	21.322	-	0.595	-	-
11-Sep-10	-	-	-	0.012	-	0.133	97.142	21.301	-	0.570	-	-
12-Sep-10	-	-	-	0.011	-	0.131	97.142	21.280	-	0.542	-	-
13-Sep-10	-	-	-	0.012	-	0.128	97.142	21.259	-	0.517	-	-
14-Sep-10	-	-	-	0.011	-	0.124	97.142	21.238	-	0.493	-	-
15-Sep-10	-	-	-	0.010	-	0.121	97.142	21.217	-	0.481	-	-
16-Sep-10	-	-	-	0.010	-	0.121	97.142	21.195	-	0.458	-	-
17-Sep-10	-	-	-	0.010	-	0.124	97.142	21.174	-	0.449	-	-
18-Sep-10	-	-	-	0.010	-	0.122	97.142	21.153	-	0.440	-	-
19-Sep-10	-	-	-	0.009	-	0.118	97.142	21.132	-	0.424	-	-
20-Sep-10	-	-	-	0.009	-	0.114	97.142	21.111	-	0.411	-	-
21-Sep-10	-	-	-	0.008	-	0.110	97.142	21.090	-	0.399	-	-
22-Sep-10	-	-	-	0.008	-	0.106	97.142	21.069	-	0.428	-	-
23-Sep-10	-	-	-	0.007	-	0.103	97.142	21.048	-	0.548	-	-
24-Sep-10	-	-	-	0.007	-	0.100	97.142	21.027	-	0.606	-	-
25-Sep-10	-	-	-	0.007	-	0.097	97.142	21.006	-	0.616	-	-
26-Sep-10	-	-	-	0.007	-	0.096	97.142	20.984	-	0.600	-	-
27-Sep-10	-	-	-	0.007	-	0.094	97.142	20.963	-	0.624	-	-
28-Sep-10	-	-	-	0.007	-	0.092	97.142	20.942	-	0.648	-	-
29-Sep-10	-	-	-	0.007	-	0.091	97.142	20.921	-	0.647	-	-
30-Sep-10	-	-	-	0.007	-	0.089	97.142	20.900	-	0.626	-	-
01-Oct-10	-	-	-	0.007	-	0.086	97.142	20.879	-	0.613	-	-
02-Oct-10	-	-	-	0.007	-	0.084	97.142	20.858	-	0.599	-	-
03-Oct-10	-	-	-	0.007	-	0.082	97.142	20.837	-	0.586	-	-
04-Oct-10	-	-	-	0.007	-	0.078	97.142	20.816	-	0.573	-	-
05-Oct-10	-	-	-	0.006	-	0.079	97.142	20.795	-	0.597	-	-
06-Oct-10	-	-	-	0.006	-	0.078	97.131	20.116	-	0.917	-	-
07-Oct-10	-	-	-	0.006	-	0.077	97.131	20.105	-	0.894	-	-
08-Oct-10	-	-	-	0.006	-	0.075	97.131	20.094	-	0.835	-	-
09-Oct-10	-	-	-	0.006	-	0.073	97.131	20.082	-	0.962	-	-
10-Oct-10	-	-	-	0.006	-	0.070	97.131	20.071	-	1.015	-	-
11-Oct-10	-	-	-	0.005	-	0.068	97.131	20.060	-	0.974	-	-
12-Oct-10	-	-	-	0.005	-	0.066	97.131	20.049	-	0.944	-	-
13-Oct-10	-	-	-	0.005	-	0.063	97.131	20.038	-	0.921	-	-
14-Oct-10	-	-	-	0.005	-	0.061	97.131	20.027	-	0.887	-	-
15-Oct-10	-	-	-	0.005	-	0.061	97.131	20.016	-	0.842	-	-
16-Oct-10	-	-	-	0.005	-	0.058	97.131	20.005	-	0.810	-	-
17-Oct-10	-	-	-	0.004	-	0.057	97.131	19.994	-	0.790	-	-
18-Oct-10	-	-	-	0.004	-	0.058	97.131	19.982	-	0.769	-	-
19-Oct-10	-	-	-	0.004	-	0.060	97.131	19.971	-	0.736	-	-
20-Oct-10	-	-	-	0.004	-	0.060	97.131	19.960	-	0.716	-	-
21-Oct-10	-	-	-	0.004	-	0.059	97.131	19.949	-	0.692	-	-
22-Oct-10	-	-	-	0.004	-	0.060	97.131	19.938	-	0.667	-	-
23-Oct-10	-	-	-	0.004	-	0.060	97.131	19.927	-	0.658	-	-
24-Oct-10	-	-	-	0.004	-	0.059	97.132	19.916	-	0.640	-	-
25-Oct-10	-	-	-	0.004	-	0.058	97.132	19.905	-	0.623	-	-
26-Oct-10	-	-	-	0.004	-	-	97.132	19.894	-	0.572	-	-
27-Oct-10	-	-	-	-	-	-	97.132	19.882	-	0.543	-	-
28-Oct-10	-	-	-	-	-	-	97.132	19.871	-	0.532	-	-
29-Oct-10	-	-	-	-	-	-	97.132	19.860	-	0.539	-	-
30-Oct-10	-	-	-	-	-	-	97.132	19.849	-	0.542	-	-
31-Oct-10	-	-	-	-	-	-	97.132	19.838	-	0.492	-	-
01-Nov-10	-	-	-	-	-	-	97.132	19.827	-	0.515	-	-
02-Nov-10	-	-	-	-	-	-	97.132	19.816	-	0.535	-	-
03-Nov-10	-	-	-	-	-	-	97.132	19.805	-	0.549	-	-
04-Nov-10	-	-	-	-	-	-	97.132	19.794	-	0.598	-	-
05-Nov-10	-	-	-	-	-	-	97.132	19.782	-	0.603	-	-
06-Nov-10	-	-	-	-	-	-	97.119	19.016	-	-	-	-
07-Nov-10	-	-	-	-	-	-	97.119	19.018	-	-	-	-
08-Nov-10	-	-	-	-	-	-	97.119	19.020	-	-	-	-
09-Nov-10	-	-	-	-	-	-	97.119	19.021	-	-	-	-
10-Nov-10	-	-	-	-	-	-	97.119	19.023	-	-	-	-
11-Nov-10	-	-	-	-	-	-	97.119	19.024	-	-	-	-
12-Nov-10	-	-	-	-	-	-	97.119	19.026	-	-	-	-
13-Nov-10	-	-	-	-	-	-	97.119	19.027	-	-	-	-
14-Nov-10	-	-	-	-	-	-	97.119	19.029	-	-	-	-
15-Nov-10	-	-	-	-	-	-	97.119	19.031	-	-	-	-
16-Nov-10	-	-	-	-	-	-	97.119	19.032	-	-	-	-
17-Nov-10	-	-	-	-	-	-	97.119	19.034	-	-	-	-
18-Nov-10	-	-	-	-	-	-	97.119	19.035	-	-	-	-
19-Nov-10	-	-	-	-	-	-	97.119	19.037	-	-	-	-
20-Nov-10	-	-	-	-	-	-	97.119	19.039	-	-	-	-
21-Nov-10	-	-	-	-	-	-	97.119	19.040	-	-	-	-
22-Nov-10	-	-	-	-	-	-	97.119	19.042	-	-	-	-
23-Nov-10	-	-	-	-	-	-	97.119	19.043	-	-	-	-
24-Nov-10	-	-	-	-	-	-	97.119	19.045	-	-	-	-
25-Nov-10	-	-	-	-	-	-	97.119	19.046	-	-	-	-
26-Nov-10	-	-	-	-	-	-	97.119	19.048	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
27-Nov-10	-	-	-	-	-	-	97.119	19.050	-	-	-	-
28-Nov-10	-	-	-	-	-	-	97.119	19.051	-	-	-	-
29-Nov-10	-	-	-	-	-	-	97.119	19.053	-	-	-	-
30-Nov-10	-	-	-	-	-	-	97.119	19.054	-	-	-	-
01-Dec-10	-	-	-	-	-	-	97.119	19.056	-	-	-	-
02-Dec-10	-	-	-	-	-	-	97.119	19.057	-	-	-	-
03-Dec-10	-	-	-	-	-	-	97.119	19.059	-	-	-	-
04-Dec-10	-	-	-	-	-	-	97.119	19.061	-	-	-	-
05-Dec-10	-	-	-	-	-	-	97.119	19.062	-	-	-	-
06-Dec-10	-	-	-	-	-	-	96.964	10.768	-	-	-	-
07-Dec-10	-	-	-	-	-	-	96.909	8.251	-	-	-	-
08-Dec-10	-	-	-	-	-	-	96.887	7.386	-	-	-	-
09-Dec-10	-	-	-	-	-	-	97.390	39.996	-	-	-	-
10-Dec-10	-	-	-	-	-	-	97.045	15.249	-	-	-	-
11-Dec-10	-	-	-	-	-	-	97.009	12.885	-	-	-	-
12-Dec-10	-	-	-	-	-	-	97.010	12.913	-	-	-	-
13-Dec-10	-	-	-	-	-	-	97.010	12.940	-	-	-	-
14-Dec-10	-	-	-	-	-	-	97.010	12.968	-	-	-	-
15-Dec-10	-	-	-	-	-	-	97.010	12.995	-	-	-	-
16-Dec-10	-	-	-	-	-	-	97.011	13.023	-	-	-	-
17-Dec-10	-	-	-	-	-	-	97.011	13.051	-	-	-	-
18-Dec-10	-	-	-	-	-	-	97.011	13.078	-	-	-	-
19-Dec-10	-	-	-	-	-	-	97.012	13.106	-	-	-	-
20-Dec-10	-	-	-	-	-	-	97.012	13.133	-	-	-	-
21-Dec-10	-	-	-	-	-	-	97.012	13.161	-	-	-	-
22-Dec-10	-	-	-	-	-	-	97.013	13.189	-	-	-	-
23-Dec-10	-	-	-	-	-	-	97.013	13.216	-	-	-	-
24-Dec-10	-	-	-	-	-	-	97.013	13.244	-	-	-	-
25-Dec-10	-	-	-	-	-	-	97.013	13.271	-	-	-	-
26-Dec-10	-	-	-	-	-	-	97.014	13.299	-	-	-	-
27-Dec-10	-	-	-	-	-	-	97.014	13.327	-	-	-	-
28-Dec-10	-	-	-	-	-	-	97.014	13.354	-	-	-	-
29-Dec-10	-	-	-	-	-	-	97.015	13.382	-	-	-	-
30-Dec-10	-	-	-	-	-	-	97.015	13.409	-	-	-	-
31-Dec-10	-	-	-	-	-	-	97.015	13.437	-	-	-	-
01-Jan-11	-	-	-	-	-	-	97.015	13.464	-	-	-	-
02-Jan-11	-	-	-	-	-	-	97.016	13.492	-	-	-	-
03-Jan-11	-	-	-	-	-	-	97.016	13.520	-	-	-	-
04-Jan-11	-	-	-	-	-	-	97.016	13.547	-	-	-	-
05-Jan-11	-	-	-	-	-	-	97.017	13.575	-	-	-	-
06-Jan-11	-	-	-	-	-	-	97.017	13.602	-	-	-	-
07-Jan-11	-	-	-	-	-	-	97.017	13.630	-	-	-	-
08-Jan-11	-	-	-	-	-	-	97.017	13.658	-	-	-	-
09-Jan-11	-	-	-	-	-	-	97.018	13.685	-	-	-	-
10-Jan-11	-	-	-	-	-	-	97.018	13.713	-	-	-	-
11-Jan-11	-	-	-	-	-	-	97.018	13.740	-	-	-	-
12-Jan-11	-	-	-	-	-	-	97.019	13.768	-	-	-	-
13-Jan-11	-	-	-	-	-	-	97.019	13.796	-	-	-	-
14-Jan-11	-	-	-	-	-	-	97.019	13.823	-	-	-	-
15-Jan-11	-	-	-	-	-	-	97.019	13.851	-	-	-	-
16-Jan-11	-	-	-	-	-	-	97.020	13.878	-	-	-	-
17-Jan-11	-	-	-	-	-	-	97.020	13.906	-	-	-	-
18-Jan-11	-	-	-	-	-	-	97.020	13.934	-	-	-	-
19-Jan-11	-	-	-	-	-	-	97.021	13.961	-	-	-	-
20-Jan-11	-	-	-	-	-	-	97.021	13.989	-	-	-	-
21-Jan-11	-	-	-	-	-	-	97.021	14.016	-	-	-	-
22-Jan-11	-	-	-	-	-	-	97.021	14.044	-	-	-	-
23-Jan-11	-	-	-	-	-	-	97.022	14.072	-	-	-	-
24-Jan-11	-	-	-	-	-	-	97.022	14.099	-	-	-	-
25-Jan-11	-	-	-	-	-	-	97.022	14.127	-	-	-	-
26-Jan-11	-	-	-	-	-	-	97.023	14.154	-	-	-	-
27-Jan-11	-	-	-	-	-	-	97.023	14.182	-	-	-	-
28-Jan-11	-	-	-	-	-	-	97.023	14.210	-	-	-	-
29-Jan-11	-	-	-	-	-	-	97.023	14.237	-	-	-	-
30-Jan-11	-	-	-	-	-	-	97.024	14.265	-	-	-	-
31-Jan-11	-	-	-	-	-	-	97.024	14.292	-	-	-	-
01-Feb-11	-	-	-	-	-	-	97.024	14.320	-	-	-	-
02-Feb-11	-	-	-	-	-	-	97.025	14.347	-	-	-	-
03-Feb-11	-	-	-	-	-	-	97.025	14.375	-	-	-	-
04-Feb-11	-	-	-	-	-	-	97.025	14.403	-	-	-	-
05-Feb-11	-	-	-	-	-	-	97.025	14.430	-	-	-	-
06-Feb-11	-	-	-	-	-	-	97.026	14.458	-	-	-	-
07-Feb-11	-	-	-	-	-	-	97.026	14.485	-	-	-	-
08-Feb-11	-	-	-	-	-	-	97.026	14.513	-	-	-	-
09-Feb-11	-	-	-	-	-	-	97.027	14.541	-	-	-	-
10-Feb-11	-	-	-	-	-	-	97.027	14.568	-	-	-	-
11-Feb-11	-	-	-	-	-	-	97.027	14.596	-	-	-	-
12-Feb-11	-	-	-	-	-	-	97.027	14.623	-	-	-	-
13-Feb-11	-	-	-	-	-	-	97.028	14.651	-	-	-	-
14-Feb-11	-	-	-	-	-	-	97.028	14.679	-	-	-	-
15-Feb-11	-	-	-	-	-	-	97.028	14.706	-	-	-	-
16-Feb-11	-	-	-	-	-	-	97.029	14.734	-	-	-	-
17-Feb-11	-	-	-	-	-	-	97.029	14.761	-	-	-	-
18-Feb-11	-	-	-	-	-	-	97.029	14.789	-	-	-	-
19-Feb-11	-	-	-	-	-	-	97.030	14.817	-	-	-	-
20-Feb-11	-	-	-	-	-	-	97.030	14.844	-	-	-	-
21-Feb-11	-	-	-	-	-	-	97.030	14.872	-	-	-	-
22-Feb-11	-	-	-	-	-	-	97.030	14.899	-	-	-	-
23-Feb-11	-	-	-	-	-	-	97.031	14.927	-	-	-	-
24-Feb-11	-	-	-	-	-	-	97.031	14.955	-	-	-	-
25-Feb-11	-	-	-	-	-	-	97.031	14.982	-	-	-	-
26-Feb-11	-	-	-	-	-	-	97.032	15.010	-	-	-	-
27-Feb-11	-	-	-	-	-	-	97.032	15.037	-	-	-	-
28-Feb-11	-	-	-	-	-	-	97.032	15.065	-	-	-	-
01-Mar-11	-	-	-	-	-	-	97.032	15.093	-	-	-	-
02-Mar-11	-	-	-	-	-	-	97.033	15.120	-	-	-	-
03-Mar-11	-	-	-	-	-	-	97.033	15.148	-	-	-	-
04-Mar-11	-	-	-	-	-	-	97.033	15.175	-	-	-	-
05-Mar-11	-	-	-	-	-	-	97.034	15.203	-	-	-	-
06-Mar-11	-	-	-	-	-	-	97.034	15.231	-	-	-	-
07-Mar-11	-	-	-	-	-	-	97.034	15.258	-	-	-	-
08-Mar-11	-	-	-	-	-	-	97.034	15.286	-	-	-	-
09-Mar-11	-	-	-	-	-	-	97.035	15.313	-	-	-	-
10-Mar-11	-	-	-	-	-	-	97.035	15.341	-	-	-	-
11-Mar-11	-	-	-	-	-	-	97.035	15.368	-	-	-	-
12-Mar-11	-	-	-	-	-	-	97.036	15.396	-	-	-	-
13-Mar-11	-	-	-	-	-	-	97.036	15.424	-	-	-	-
14-Mar-11	-	-	-	-	-	-	97.036	15.451	-	-	-	-
15-Mar-11	-	-	-	-	-	-	97.036	15.479	-	-	-	-
16-Mar-11	-	-	-	-	-	-	97.037	15.506	-	-	-	-
17-Mar-11	-	-	-	-	-	-	97.037	15.534	-	-	-	-
18-Mar-11	-	-	-	-	-	-	97.037	15.562	-	-	-	-
19-Mar-11	-	-	-	-	-	-	97.038	15.589	-	-	-	-
20-Mar-11	-	-	-	-	-	-	97.038	15.617	-	-	-	-
21-Mar-11	-	-	-	-	-	-	97.038	15.644	-	-	-	-
22-Mar-11	-	-	-	-	-	-	97.038	15.672	-	-	-	-
23-Mar-11	-	-	-	-	-	-	97.039	15.700	-	-	-	-
24-Mar-11	-	-	-	-	-	-	97.039	15.727	-	-	-	-
25-Mar-11	-	-	-	-	-	-	97.039	15.755	-	-	-	-
26-Mar-11	-	-	-	-	-	-	97.040	15.782	-	-	-	-
27-Mar-11	-	-	-	-	-	-	97.040	15.810	-	-	-	-
28-Mar-11	-	-	-	-	-	-	97.040	15.838	-	-	-	-
29-Mar-11	-	-	-	-	-	-	97.040	15.865	-	-	-	-
30-Mar-11	-	-	-	-	-	-	97.041	15.893	-	-	-	-
31-Mar-11	-	-	-	-	-	-	97.041	15.920	-	-	-	-
01-Apr-11	-	-	-	-	-	-	97.041	15.948	-	-	-	-
02-Apr-11	-	-	-	-	-	-	97.042	15.976	-	-	-	-
03-Apr-11	-	-	-	-	-	-	97.042	16.003	-	-	-	-
04-Apr-11	-	-	-	-	-	-	97.042	16.031	-	-	-	-
05-Apr-11	-	-	-	-	-	-	97.042	16.058	-	-	-	-
06-Apr-11	-	-	-	-	-	-	97.043	16.086	-	-	-	-
07-Apr-11	-	-	-	-	-	-	97.043	16.114	-	-	-	-
08-Apr-11	-	-	-	-	-	-	97.043	16.141	-	-	-	-
09-Apr-11	-	-	-	-	-	-	97.044	16.169	-	-	-	-
10-Apr-11	-	-	-	-	-	-	97.044	16.196	-	-	-	-
11-Apr-11	-	-	-	-	-	-	97.044	16.224	-	-	-	-
12-Apr-11	-	-	-	-	-	-	97.045	16.251	-	-	-	-
13-Apr-11	-	-	-	-	-	-	97.045	16.279	-	-	-	-
14-Apr-11	-	-	-	-	-	-	97.045	16.307	-	-	-	-
15-Apr-11	-	-	-	-	-	-	97.045	16.334	-	-	-	-
16-Apr-11	-	-	-	-	-	-	97.046	16.362	-	-	-	-
17-Apr-11	-	-	-	-	-	-	97.046	16.389	-	-	-	-
18-Apr-11	-	-	-	-	-	-	97.046	16.417	-	-	-	-
19-Apr-11	-	-	-	-	-	-	97.047	16.445	-	-	-	-
20-Apr-11	-	-	-	-	-	-	97.047	16.472	-	-	-	-
21-Apr-11	-	-	-	-	-	-	97.047	16.500	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
22-Apr-11	-	-	-	-	-	-	97.047	16.527	-	-	-	-
23-Apr-11	-	-	-	-	-	-	97.048	16.555	-	-	-	-
24-Apr-11	-	-	-	-	-	-	97.048	16.583	-	-	-	-
25-Apr-11	-	-	-	-	-	-	97.048	16.610	-	-	-	-
26-Apr-11	-	-	-	-	-	-	97.049	16.638	-	-	-	-
27-Apr-11	-	-	-	-	-	-	97.049	16.665	-	-	-	-
28-Apr-11	-	-	-	-	-	-	97.049	16.693	-	-	-	-
29-Apr-11	-	-	-	-	-	-	97.049	16.721	-	-	-	-
30-Apr-11	-	-	-	-	-	-	97.050	16.748	-	-	-	-
01-May-11	-	-	-	-	-	-	97.050	16.776	-	-	-	-
02-May-11	-	-	-	-	-	-	97.050	16.803	-	-	-	-
03-May-11	-	-	-	-	-	-	97.051	16.831	-	-	-	-
04-May-11	-	-	-	-	-	-	97.051	16.859	-	-	-	-
05-May-11	10.4	0	-	-	-	-	97.051	16.886	-	-	-	-
06-May-11	7.9	0.2	99.021	-	-	-	97.051	16.914	-	-	-	-
07-May-11	4.3	0	99.043	-	-	0.066	97.052	16.941	-	-	-	-
08-May-11	7.9	1	99.054	-	-	0.063	97.052	16.969	-	-	-	-
09-May-11	12.3	0	98.611	-	-	0.060	97.052	16.997	-	-	-	-
10-May-11	15.0	0	98.589	-	-	0.058	97.053	17.024	-	-	-	-
11-May-11	15.6	0	98.590	-	-	0.055	97.053	17.052	-	-	-	-
12-May-11	14.5	0	98.591	-	-	0.053	97.053	17.079	-	-	-	-
13-May-11	14.3	0	98.592	-	-	0.050	97.053	17.107	-	-	-	-
14-May-11	17.1	0	98.593	-	-	0.048	97.054	17.135	-	-	-	-
15-May-11	18.8	0	98.593	-	-	0.045	97.054	17.162	-	-	-	-
16-May-11	20.0	0	98.594	-	-	0.042	97.054	17.190	-	-	-	-
17-May-11	21.0	0	98.595	-	-	0.040	97.055	17.217	-	-	-	-
18-May-11	17.5	0	98.596	-	-	0.039	97.055	17.245	-	-	-	-
19-May-11	14.8	0	98.596	-	-	0.038	97.055	17.272	-	-	-	-
20-May-11	15.5	0	98.597	-	-	0.037	97.055	17.300	-	-	-	-
21-May-11	15.6	0	98.598	-	-	0.035	97.056	17.328	-	-	-	-
22-May-11	10.6	0.4	98.599	-	-	0.034	97.056	17.355	-	-	-	-
23-May-11	7.1	0	98.599	-	-	0.033	97.056	17.383	-	-	-	-
24-May-11	8.3	0	98.600	-	-	0.029	97.057	17.410	-	-	-	-
25-May-11	9.1	0	98.601	-	-	0.028	97.057	17.438	-	-	-	-
26-May-11	8.8	0	98.602	-	-	0.028	97.057	17.466	-	-	-	-
27-May-11	12.1	0	98.603	-	-	0.027	97.057	17.493	-	-	-	-
28-May-11	6.7	0	98.603	-	-	0.025	97.058	17.521	-	-	-	-
29-May-11	7.0	0	98.604	-	-	0.024	97.058	17.548	-	-	-	-
30-May-11	10.3	0.4	98.605	-	-	0.023	97.058	17.576	-	-	-	-
31-May-11	12.1	0	98.606	-	-	0.023	97.059	17.604	-	-	-	-
01-Jun-11	16.3	0	98.606	-	-	0.022	97.059	17.631	-	-	-	-
02-Jun-11	16.6	0	98.607	-	-	0.021	97.059	17.659	-	-	-	-
03-Jun-11	1.7	0	98.608	-	-	0.022	97.060	17.686	-	-	-	-
04-Jun-11	4.6	0	98.609	-	-	0.021	97.060	17.714	-	-	-	-
05-Jun-11	9.2	0	98.609	-	-	0.019	97.060	17.742	-	-	-	-
06-Jun-11	10.8	0	98.610	-	-	0.019	97.060	17.769	-	-	-	-
07-Jun-11	9.5	0	98.611	-	-	0.018	97.061	17.797	-	-	-	-
08-Jun-11	10.5	0	98.612	-	-	0.017	97.061	17.824	-	-	-	-
09-Jun-11	17.7	0	98.612	-	-	0.016	97.061	17.852	-	-	-	-
10-Jun-11	20.8	0.2	98.613	-	-	0.015	97.062	17.880	-	-	-	-
11-Jun-11	16.8	0	98.614	-	-	0.015	97.062	17.907	-	-	-	-
12-Jun-11	13.9	0	98.615	-	-	0.014	97.062	17.935	-	-	-	-
13-Jun-11	17.8	0	98.616	-	-	0.013	97.062	17.962	-	-	-	-
14-Jun-11	15.8	4	98.616	-	-	0.013	97.063	17.990	-	-	-	-
15-Jun-11	17.6	0	98.617	-	-	0.013	97.063	18.018	-	-	-	-
16-Jun-11	13.9	3.2	98.618	-	-	0.015	97.063	18.045	-	-	-	-
17-Jun-11	13.4	0.2	98.619	-	-	0.018	97.064	18.073	-	-	-	-
18-Jun-11	16.8	1	98.619	-	-	0.018	97.064	18.100	-	0.216	-	-
19-Jun-11	18.0	0	98.620	-	-	0.016	97.064	18.128	-	-	-	-
20-Jun-11	17.9	0	98.621	-	-	0.015	97.064	18.155	-	-	-	-
21-Jun-11	18.4	0	98.622	-	-	0.015	97.065	18.183	-	-	-	-
22-Jun-11	19.9	0	98.622	-	-	0.014	97.065	18.211	-	-	-	-
23-Jun-11	20.2	0	98.623	-	-	0.013	97.065	18.238	-	-	-	-
24-Jun-11	16.9	1.2	98.624	-	-	0.012	97.066	18.266	-	-	-	-
25-Jun-11	14.8	4	98.625	-	-	0.014	97.066	18.293	-	-	-	-
26-Jun-11	12.3	0.2	98.626	-	-	0.016	97.066	18.321	-	-	-	-
27-Jun-11	10.5	0	98.626	-	-	0.014	97.066	18.349	-	-	-	-
28-Jun-11	14.0	0.2	98.627	-	-	0.013	97.067	18.376	-	-	-	-
29-Jun-11	21.0	0.4	98.628	-	-	0.012	97.067	18.404	-	-	-	-
30-Jun-11	20.1	0.2	98.629	-	-	0.011	97.067	18.431	-	-	-	-
01-Jul-11	15.0	1.2	98.629	-	-	0.010	97.068	18.459	-	-	-	-
02-Jul-11	17.3	0	98.630	-	-	0.009	97.068	18.487	-	-	-	-
03-Jul-11	17.0	13.8	98.631	-	-	0.011	97.068	18.514	-	-	-	-
04-Jul-11	17.1	0	98.632	-	-	0.025	97.068	18.542	-	-	-	-
05-Jul-11	18.8	0	98.632	-	-	0.018	97.069	18.569	-	-	-	-
06-Jul-11	19.1	0	98.633	-	-	0.014	97.069	18.597	-	-	-	-
07-Jul-11	16.6	2.6	98.634	-	-	0.014	97.069	18.625	-	-	-	-
08-Jul-11	15.5	15.8	98.635	-	-	0.017	97.070	18.652	-	-	-	-
09-Jul-11	15.0	7.4	98.635	-	-	0.025	97.070	18.680	-	-	-	-
10-Jul-11	18.2	0.8	98.636	-	-	0.028	97.070	18.707	-	-	-	-
11-Jul-11	17.0	0	98.637	-	-	0.023	97.070	18.735	-	-	-	-
12-Jul-11	19.2	0	98.638	-	-	0.020	97.071	18.763	-	-	-	-
13-Jul-11	19.9	0	98.639	-	-	0.017	97.071	18.790	-	-	-	-
14-Jul-11	18.5	0.4	98.639	-	-	0.015	97.071	18.818	-	-	-	-
15-Jul-11	18.8	0.6	98.640	-	-	0.014	97.072	18.845	-	-	-	-
16-Jul-11	17.0	32.6	98.641	-	-	0.013	97.072	18.873	-	-	-	-
17-Jul-11	20.3	0	98.642	-	-	0.011	97.072	18.901	-	-	-	-
18-Jul-11	22.1	0	98.642	-	-	0.011	97.072	18.928	-	-	-	-
19-Jul-11	20.5	0	98.643	-	-	0.010	97.073	18.956	-	-	-	-
20-Jul-11	14.6	9.4	98.644	-	-	0.010	97.073	18.983	-	-	-	-
21-Jul-11	14.5	7.6	98.645	-	-	0.013	97.073	19.011	-	1.225	-	-
22-Jul-11	16.9	0.2	98.645	-	-	0.014	97.074	19.038	-	1.188	-	-
23-Jul-11	14.6	0.2	98.646	-	-	0.012	97.074	19.066	-	1.109	-	-
24-Jul-11	16.4	0.2	98.647	-	-	0.012	97.074	19.094	-	0.995	-	-
25-Jul-11	19.4	0	98.648	-	-	0.011	97.075	19.121	-	0.962	-	-
26-Jul-11	19.4	0	98.649	-	-	0.013	97.075	19.149	-	0.816	-	-
27-Jul-11	16.4	0	98.649	-	-	0.014	97.075	19.176	-	0.707	-	-
28-Jul-11	17.6	0	98.650	-	-	0.015	97.075	19.204	-	0.630	-	-
29-Jul-11	16.5	2.6	98.651	-	-	0.014	97.076	19.232	-	0.560	-	-
30-Jul-11	16.4	0	98.652	-	-	0.014	97.076	19.259	-	0.510	-	-
31-Jul-11	17.9	1.8	98.652	-	-	0.013	97.076	19.287	-	0.450	-	-
01-Aug-11	15.8	0.2	98.653	-	-	0.014	97.077	19.314	-	0.413	-	-
02-Aug-11	18.0	0	98.654	-	-	0.013	97.077	19.342	-	0.379	-	-
03-Aug-11	13.9	0	98.655	-	-	0.012	97.077	19.370	-	0.340	-	-
04-Aug-11	15.2	0	98.655	-	-	0.011	97.077	19.397	-	0.331	-	-
05-Aug-11	17.9	0	98.656	-	-	0.010	97.078	19.425	-	0.295	-	-
06-Aug-11	18.9	0.2	98.657	-	-	0.009	97.078	19.452	-	0.264	-	-
07-Aug-11	17.0	11.8	98.658	-	-	0.010	97.078	19.480	-	0.242	-	-
08-Aug-11	16.3	2.6	98.658	-	-	0.009	97.079	19.508	-	0.215	-	-
09-Aug-11	18.0	0.2	98.659	-	-	0.009	97.079	19.535	-	0.182	-	-
10-Aug-11	15.8	0.2	98.660	-	-	0.009	97.079	19.563	-	0.188	-	-
11-Aug-11	15.0	0	98.661	-	-	0.009	97.079	19.590	-	0.184	-	-
12-Aug-11	17.2	0	98.662	-	-	0.008	97.080	19.618	-	0.162	-	-
13-Aug-11	15.4	2.6	98.662	-	-	0.009	97.080	19.646	-	0.182	-	-
14-Aug-11	16.0	3.8	98.663	-	-	0.011	97.080	19.673	-	0.181	-	-
15-Aug-11	16.2	1.6	98.664	-	-	0.015	97.081	19.701	-	0.163	-	-
16-Aug-11	15.1	0	98.665	-	-	0.012	97.081	19.728	-	0.146	-	-
17-Aug-11	15.1	0	98.665	-	-	0.011	97.081	19.756	-	0.142	-	-
18-Aug-11	13.0	0	98.666	-	-	0.011	97.081	19.784	-	0.151	-	-
19-Aug-11	11.5	0.6	98.667	-	-	0.011	97.082	19.811	-	0.158	-	-
20-Aug-11	13.3	0	98.668	-	-	0.011	97.082	19.839	-	0.160	-	-
21-Aug-11	22.0	0	98.668	-	-	0.010	97.082	19.866	-	0.160	-	-
22-Aug-11	21.5	0	98.669	-	-	0.010	97.083	19.894	-	0.172	-	-
23-Aug-11	18.0	0	98.670	-	-	0.010	97.083	19.922	-	0.176	-	-
24-Aug-11	16.8	0	98.671	-	-	0.009	97.083	19.949	-	0.471	-	-
25-Aug-11	14.3	0	98.672	-	-	0.010	97.083	19.977	-	0.638	-	-
26-Aug-11	14.0	0	98.672	-	-	0.010	97.084	20.004	-	0.937	-	-
27-Aug-11	18.3	0	98.673	-	-	0.009	97.084	20.032	-	1.364	-	-
28-Aug-11	15.0	0	98.674	-	-	0.008	97.084	20.059	-	1.520	-	-
29-Aug-11	13.9	15	98.675	-	-	0.013	97.085	20.087	-	1.544	-	-
30-Aug-11	13.2	0	98.675	-	-	0.019	97.085	20.115	-	1.479	-	-
31-Aug-11	10.9	0	98.676	-	-	0.016	97.085	20.142	-	1.346	-	-
01-Sep-11	9.0	0.6	98.677	-	-	0.015	97.085	20.170	-	1.190	-	-
02-Sep-11	10.1	0	98.678	-	-	0.013	97.086	20.197	-	1.039	-	-
03-Sep-11	12.1	0	98.678	-	-	0.012	97.086	20.225	-	0.912	-	-
04-Sep-11	18.9	0	98.679	-	-	0.012	97.086	20.253	-	0.816	-	-
05-Sep-11	18.5	0	98.680	-	-	0.012	97.087	20.280	-	0.754	-	-
06-Sep-11	17.9	0.6	98.681	-	-	0.012	97.087	20.308	-	0.706	-	-
07-Sep-11	21.9	0	98.682	-	-	0.012	97.087	20.335	-	0.688	-	-
08-Sep-11	20.2	0	98.682	-	-	0.011	97.087	20.363	-	0.672	-	-
09-Sep-11	22.5	0	98.683	-	-	0.010	97.088	20.391	-	0.669	-	-
10-Sep-11	15.8	0	98.684	-	-	0.009	97.088	20.418	-	0.635	-	-
11-Sep-11	11.8	0	98.685	-	-	0.009	97.088	20.446	-	0.623	-	-
12-Sep-11	5.9	0	98.685	-	-	0.011	97.089	20.473	-	0.577	-	-
13-Sep-11	1.8	0	98.686	-	-	0.012	97.089	20.501	-	0.513	-	-
14-Sep-11	9.4	0	98.687	-	-	0.012	97.089	20.529	-	0.458	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
15-Sep-11	11.8	0	98.688	-	-	0.012	97.090	20.556	-	0.417	-	-
16-Sep-11	9.4	4.6	98.688	-	-	0.013	97.090	20.584	-	0.385	-	-
17-Sep-11	10.7	22.6	98.689	-	-	0.017	97.090	20.611	-	0.372	-	-
18-Sep-11	10.0	6.8	98.690	-	-	0.030	97.090	20.639	-	0.374	-	-
19-Sep-11	9.8	0	98.691	-	-	0.027	97.091	20.667	-	0.355	-	-
20-Sep-11	9.6	0	98.691	-	-	0.024	97.091	20.694	-	0.324	-	-
21-Sep-11	16.1	0	98.692	-	-	0.022	97.091	20.722	-	0.315	-	-
22-Sep-11	16.2	0	98.693	-	-	0.021	97.092	20.749	-	0.316	-	-
23-Sep-11	16.6	0	98.694	-	-	0.019	97.092	20.777	-	0.312	-	-
24-Sep-11	14.6	0	98.695	-	-	0.019	97.092	20.805	-	0.328	-	-
25-Sep-11	17.1	0	98.695	-	-	0.019	97.092	20.832	-	0.310	-	-
26-Sep-11	15.3	0	98.696	-	-	0.021	97.093	20.860	-	0.367	-	-
27-Sep-11	12.3	0	98.697	-	-	0.020	97.093	20.887	-	0.378	-	-
28-Sep-11	8.4	0	98.698	-	-	0.020	97.093	20.915	-	0.365	-	-
29-Sep-11	9.4	0	98.698	-	-	0.019	97.094	20.942	-	0.356	-	-
30-Sep-11	13.4	0	98.699	-	-	0.019	97.094	20.970	-	0.344	-	-
01-Oct-11	8.7	0	98.700	-	-	0.020	97.094	20.998	-	0.332	-	-
02-Oct-11	5.0	0.2	98.701	-	-	0.021	97.094	21.025	-	0.322	-	-
03-Oct-11	6.8	0.4	98.701	-	-	0.021	97.095	21.053	-	0.310	-	-
04-Oct-11	9.7	3	98.702	-	-	0.021	97.095	21.080	-	0.298	-	-
05-Oct-11	9.3	0.2	98.703	-	-	0.023	97.095	21.108	-	0.291	-	-
06-Oct-11	8.5	0	98.704	-	-	0.023	97.096	21.136	-	0.286	-	-
07-Oct-11	8.9	0	98.705	-	-	0.023	97.096	21.163	-	0.276	-	-
08-Oct-11	5.8	0	98.705	-	-	0.022	97.096	21.191	-	0.259	-	-
09-Oct-11	8.0	0	98.706	-	-	0.019	97.096	21.218	-	0.255	-	-
10-Oct-11	7.3	0	98.707	-	-	0.020	97.097	21.246	-	0.257	-	-
11-Oct-11	4.0	0	98.708	-	-	0.020	97.097	21.274	-	0.253	-	-
12-Oct-11	4.1	0	98.708	-	-	0.021	97.097	21.301	-	0.246	-	-
13-Oct-11	0.8	0	98.709	-	-	0.021	97.098	21.329	-	0.240	-	-
14-Oct-11	5.0	0	98.710	-	-	0.020	97.098	21.356	-	0.219	-	-
15-Oct-11	3.1	0	98.711	-	-	0.021	97.098	21.384	-	0.223	-	-
16-Oct-11	2.2	0	98.711	-	-	0.022	97.098	21.412	-	0.242	-	-
17-Oct-11	2.1	0	98.712	-	-	-	97.099	21.439	-	0.284	-	-
18-Oct-11	3.9	0	98.713	-	-	-	97.099	21.467	-	0.285	-	-
19-Oct-11	9.7	0	98.714	-	-	-	97.099	21.494	-	0.285	-	-
20-Oct-11	6.3	1.6	98.714	-	-	-	97.100	21.522	-	0.292	-	-
21-Oct-11	-0.1	0	98.715	-	-	-	97.100	21.550	-	0.293	-	-
22-Oct-11	1.2	3.6	98.716	-	-	-	97.100	21.577	-	0.298	-	-
23-Oct-11	-0.2	0	98.717	-	-	-	97.100	21.605	-	-	-	-
24-Oct-11	3.0	0	98.718	-	-	-	97.101	21.632	-	-	-	-
25-Oct-11	1.1	0	98.718	-	-	-	97.101	21.660	-	-	-	-
26-Oct-11	3.5	0.6	98.719	-	-	-	97.101	21.688	-	-	-	-
27-Oct-11	4.3	0	98.720	-	-	-	97.102	21.715	-	-	-	-
28-Oct-11	-0.6	0	98.721	-	-	-	97.102	21.743	-	-	-	-
29-Oct-11	3.1	0	98.721	-	-	-	97.102	21.770	-	-	-	-
30-Oct-11	5.3	0	98.722	-	-	-	97.102	21.798	-	-	-	-
31-Oct-11	3.7	0	98.723	-	-	-	97.103	21.826	-	-	-	-
01-Nov-11	1.5	-	98.724	-	-	-	97.103	21.853	-	-	-	-
02-Nov-11	3.7	-	98.724	-	-	-	97.103	21.881	-	-	-	-
03-Nov-11	0.2	-	98.725	-	-	-	97.104	21.908	-	-	-	-
04-Nov-11	-8.2	-	98.726	-	-	-	97.104	21.936	-	-	-	-
05-Nov-11	-5.7	-	98.727	-	-	-	97.104	21.963	-	-	-	-
06-Nov-11	-8.6	-	98.728	-	-	-	97.104	21.991	-	-	-	-
07-Nov-11	-1.6	-	98.728	-	-	-	97.105	22.019	-	-	-	-
08-Nov-11	-1.4	-	98.729	-	-	-	97.105	22.046	-	-	-	-
09-Nov-11	-6.4	-	98.730	-	-	-	97.105	22.074	-	-	-	-
10-Nov-11	-0.8	-	98.731	-	-	-	97.106	22.101	-	-	-	-
11-Nov-11	-8.5	-	98.731	-	-	-	97.106	22.129	-	-	-	-
12-Nov-11	-5.0	-	98.732	-	-	-	97.106	22.157	-	-	-	-
13-Nov-11	-2.7	-	98.733	-	-	-	97.107	22.184	-	-	-	-
14-Nov-11	-6.6	-	98.734	-	-	-	97.107	22.212	-	-	-	-
15-Nov-11	-12.9	-	98.734	-	-	-	97.107	22.239	-	-	-	-
16-Nov-11	-15.5	-	98.735	-	-	-	97.107	22.267	-	-	-	-
17-Nov-11	-14.1	-	98.736	-	-	-	97.108	22.295	-	-	-	-
18-Nov-11	-17.6	-	98.737	-	-	-	97.108	22.322	-	-	-	-
19-Nov-11	-23.7	-	98.738	-	-	-	97.108	22.350	-	-	-	-
20-Nov-11	-18.9	-	98.738	-	-	-	97.109	22.377	-	-	-	-
21-Nov-11	-22.7	-	98.739	-	-	-	97.109	22.405	-	-	-	-
22-Nov-11	-11.7	-	98.740	-	-	-	97.109	22.433	-	-	-	-
23-Nov-11	-11.1	-	98.741	-	-	-	97.109	22.460	-	-	-	-
24-Nov-11	-6.9	-	98.741	-	-	-	97.110	22.488	-	-	-	-
25-Nov-11	-3.4	-	98.742	-	-	-	97.110	22.515	-	-	-	-
26-Nov-11	-6.8	-	98.743	-	-	-	97.110	22.543	-	-	-	-
27-Nov-11	0.4	-	98.744	-	-	-	97.111	22.571	-	-	-	-
28-Nov-11	-9.6	-	98.744	-	-	-	97.111	22.598	-	-	-	-
29-Nov-11	-6.3	-	98.745	-	-	-	97.111	22.626	-	-	-	-
30-Nov-11	-12.6	-	98.746	-	-	-	97.111	22.653	-	-	-	-
01-Dec-11	-4.3	-	98.747	-	-	-	97.112	22.681	-	-	-	-
02-Dec-11	-9.4	-	98.747	-	-	-	97.112	22.709	-	-	-	-
03-Dec-11	-10.7	-	98.748	-	-	-	97.112	22.736	-	-	-	-
04-Dec-11	-9.7	-	98.749	-	-	-	97.113	22.764	-	-	-	-
05-Dec-11	-1.3	-	98.750	-	-	-	97.113	22.791	-	-	-	-
06-Dec-11	-2.8	-	98.751	-	-	-	97.113	22.819	-	-	-	-
07-Dec-11	-14.4	-	98.751	-	-	-	97.113	22.846	-	-	-	-
08-Dec-11	-24.1	-	98.752	-	-	-	97.114	22.874	-	-	-	-
09-Dec-11	-12.7	-	98.753	-	-	-	97.114	22.902	-	-	-	-
10-Dec-11	-8.6	-	98.754	-	-	-	97.114	22.929	-	-	-	-
11-Dec-11	-9.1	-	98.754	-	-	-	97.115	22.957	-	-	-	-
12-Dec-11	-6.2	-	98.755	-	-	-	97.115	22.984	-	-	-	-
13-Dec-11	-4.7	-	98.756	-	-	-	97.115	23.012	-	-	-	-
14-Dec-11	-13.1	-	98.757	-	-	-	97.115	23.040	-	-	-	-
15-Dec-11	-14.1	-	98.757	-	-	-	97.116	23.067	-	-	-	-
16-Dec-11	-8.3	-	98.758	-	-	-	97.116	23.095	-	-	-	-
17-Dec-11	-10.3	-	98.759	-	-	-	97.116	23.122	-	-	-	-
18-Dec-11	-13.4	-	98.760	-	-	-	97.117	23.150	-	-	-	-
19-Dec-11	-2.9	-	98.761	-	-	-	97.117	23.178	-	-	-	-
20-Dec-11	-7.3	-	98.761	-	-	-	97.117	23.205	-	-	-	-
21-Dec-11	-10.7	-	98.762	-	-	-	97.117	23.233	-	-	-	-
22-Dec-11	-5.8	-	98.763	-	-	-	97.118	23.260	-	-	-	-
23-Dec-11	-0.2	-	98.764	-	-	-	97.118	23.288	-	-	-	-
24-Dec-11	1.2	-	98.764	-	-	-	97.118	23.316	-	-	-	-
25-Dec-11	0.4	-	98.765	-	-	-	97.119	23.343	-	-	-	-
26-Dec-11	-9.9	-	98.766	-	-	-	97.119	23.371	-	-	-	-
27-Dec-11	-3.6	-	98.767	-	-	-	97.119	23.398	-	-	-	-
28-Dec-11	-7.2	-	98.767	-	-	-	97.119	23.426	-	-	-	-
29-Dec-11	-4.8	-	98.768	-	-	-	97.120	23.454	-	-	-	-
30-Dec-11	-9.3	-	98.769	-	-	-	97.120	23.481	-	-	-	-
31-Dec-11	-11.4	-	98.770	-	-	-	97.120	23.509	-	-	-	-
01-Jan-12	-15.5	-	98.770	-	-	-	97.121	23.536	-	-	-	-
02-Jan-12	-4.9	-	98.771	-	-	-	97.121	23.564	-	-	-	-
03-Jan-12	-5.2	-	98.772	-	-	-	97.121	23.592	-	-	-	-
04-Jan-12	-5.8	-	98.773	-	-	-	97.122	23.619	-	-	-	-
05-Jan-12	-7.0	-	98.774	-	-	-	97.122	23.647	-	-	-	-
06-Jan-12	-11.0	-	98.774	-	-	-	97.122	23.674	-	-	-	-
07-Jan-12	-10.4	-	98.775	-	-	-	97.122	23.702	-	-	-	-
08-Jan-12	2.5	-	98.776	-	-	-	97.123	23.730	-	-	-	-
09-Jan-12	1.1	-	98.777	-	-	-	97.123	23.757	-	-	-	-
10-Jan-12	-12.5	-	98.777	-	-	-	97.123	23.785	-	-	-	-
11-Jan-12	-17.2	-	98.778	-	-	-	97.124	23.812	-	-	-	-
12-Jan-12	-6.3	-	98.779	-	-	-	97.124	23.840	-	-	-	-
13-Jan-12	-6.3	-	98.780	-	-	-	97.124	23.867	-	-	-	-
14-Jan-12	-15.7	-	98.780	-	-	-	97.124	23.895	-	-	-	-
15-Jan-12	-22.9	-	98.781	-	-	-	97.125	23.923	-	-	-	-
16-Jan-12	-30.2	-	98.782	-	-	-	97.125	23.950	-	-	-	-
17-Jan-12	-31.5	-	98.783	-	-	-	97.125	23.978	-	-	-	-
18-Jan-12	-24.5	-	98.784	-	-	-	97.126	24.005	-	-	-	-
19-Jan-12	-22.5	-	98.784	-	-	-	97.126	24.033	-	-	-	-
20-Jan-12	-22.2	-	98.785	-	-	-	97.126	24.061	-	-	-	-
21-Jan-12	-23.0	-	98.786	-	-	-	97.126	24.088	-	-	-	-
22-Jan-12	-13.8	-	98.787	-	-	-	97.127	24.116	-	-	-	-
23-Jan-12	-11.0	-	98.787	-	-	-	97.127	24.143	-	-	-	-
24-Jan-12	-4.8	-	98.788	-	-	-	97.127	24.171	-	-	-	-
25-Jan-12	-6.3	-	98.789	-	-	-	97.128	24.199	-	-	-	-
26-Jan-12	-3.5	-	98.790	-	-	-	97.128	24.226	-	-	-	-
27-Jan-12	-11.9	-	98.790	-	-	-	97.128	24.254	-	-	-	-
28-Jan-12	-24.8	-	98.791	-	-	-	97.128	24.281	-	-	-	-
29-Jan-12	-14.0	-	98.792	-	-	-	97.129	24.309	-	-	-	-
30-Jan-12	-10.0	-	98.793	-	-	-	97.129	24.337	-	-	-	-
31-Jan-12	-13.8	-	98.794	-	-	-	97.129	24.364	-	-	-	-
01-Feb-12	-7.1	-	98.794	-	-	-	97.130	24.392	-	-	-	-
02-Feb-12	-7.1	-	98.795	-	-	-	97.130	24.419	-	-	-	-
03-Feb-12	1.7	-	98.796	-	-	-	97.130	24.447	-	-	-	-
04-Feb-12	1.6	-	98.797	-	-	-	97.130	24.475	-	-	-	-
05-Feb-12	-6.8	-	98.797	-	-	-	97.131	24.502	-	-	-	-
06-Feb-12	-14.7	-	98.798	-	-	-	97.131	24.530	-	-	-	-
07-Feb-12	-7.5	-	98.799	-	-	-	97.131	24.557	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
08-Feb-12	-11.5	-	98.800	-	-	-	97.132	24.585	-	-	-	-
09-Feb-12	-24.9	-	98.800	-	-	-	97.132	24.613	-	-	-	-
10-Feb-12	-21.7	-	98.801	-	-	-	97.132	24.640	-	-	-	-
11-Feb-12	-10.0	-	98.802	-	-	-	97.132	24.668	-	-	-	-
12-Feb-12	-5.5	-	98.803	-	-	-	97.133	24.695	-	-	-	-
13-Feb-12	-5.4	-	98.803	-	-	-	97.133	24.723	-	-	-	-
14-Feb-12	-5.2	-	98.804	-	-	-	97.133	24.750	-	-	-	-
15-Feb-12	-5.7	-	98.805	-	-	-	97.134	24.778	-	-	-	-
16-Feb-12	-10.4	-	98.806	-	-	-	97.134	24.806	-	-	-	-
17-Feb-12	-1.4	-	98.807	-	-	-	97.134	24.833	-	-	-	-
18-Feb-12	-3.4	-	98.807	-	-	-	97.134	24.861	-	-	-	-
19-Feb-12	-8.5	-	98.808	-	-	-	97.135	24.888	-	-	-	-
20-Feb-12	-11.7	-	98.809	-	-	-	97.135	24.916	-	-	-	-
21-Feb-12	-5.4	-	98.810	-	-	-	97.135	24.944	-	-	-	-
22-Feb-12	-8.4	-	98.810	-	-	-	97.136	24.971	-	-	-	-
23-Feb-12	-10.5	-	98.811	-	-	-	97.136	24.999	-	-	-	-
24-Feb-12	-14.9	-	98.812	-	-	-	97.136	25.026	-	-	-	-
25-Feb-12	-20.5	-	98.813	-	-	-	97.137	25.054	-	-	-	-
26-Feb-12	-20.5	-	98.813	-	-	-	97.137	25.082	-	-	-	-
27-Feb-12	-11.1	-	98.814	-	-	-	97.137	25.109	-	-	-	-
28-Feb-12	-7.1	-	98.815	-	-	-	97.137	25.137	-	-	-	-
29-Feb-12	-12.3	-	98.816	-	-	-	97.138	25.164	-	-	-	-
01-Mar-12	-15.8	-	98.817	-	-	-	97.138	25.192	-	-	-	-
02-Mar-12	-14.3	-	98.817	-	-	-	97.138	25.220	-	-	-	-
03-Mar-12	-10.6	-	98.818	-	-	-	97.139	25.247	-	-	-	-
04-Mar-12	-7.3	-	98.819	-	-	-	97.139	25.275	-	-	-	-
05-Mar-12	-13.6	-	98.820	-	-	-	97.139	25.302	-	-	-	-
06-Mar-12	-15.3	-	98.820	-	-	-	97.139	25.330	-	-	-	-
07-Mar-12	-10.2	-	98.821	-	-	-	97.140	25.358	-	-	-	-
08-Mar-12	-9.7	-	98.822	-	-	-	97.140	25.385	-	-	-	-
09-Mar-12	3.1	-	98.823	-	-	-	97.140	25.413	-	-	-	-
10-Mar-12	3.6	-	98.823	-	-	-	97.141	25.440	-	-	-	-
11-Mar-12	3.5	-	98.824	-	-	-	97.141	25.468	-	-	-	-
12-Mar-12	-0.7	-	98.825	-	-	-	97.141	25.496	-	-	-	-
13-Mar-12	-7.3	-	98.826	-	-	-	97.141	25.523	-	-	-	-
14-Mar-12	-12.6	-	98.826	-	-	-	97.142	25.551	-	-	-	-
15-Mar-12	-10.3	-	98.827	-	-	-	97.142	25.578	-	-	-	-
16-Mar-12	-0.4	-	98.828	-	-	-	97.142	25.606	-	-	-	-
17-Mar-12	-3.4	-	98.829	-	-	-	97.143	25.634	-	-	-	-
18-Mar-12	-5.2	-	98.830	-	-	-	97.143	25.661	-	-	-	-
19-Mar-12	-7.9	-	98.830	-	-	-	97.143	25.689	-	-	-	-
20-Mar-12	-8.5	-	98.831	-	-	-	97.143	25.716	-	-	-	-
21-Mar-12	-13.6	-	98.832	-	-	-	97.144	25.744	-	-	-	-
22-Mar-12	-14.0	-	98.833	-	-	-	97.144	25.771	-	-	-	-
23-Mar-12	-12.2	-	98.833	-	-	-	97.144	25.799	-	-	-	-
24-Mar-12	-4.4	-	98.834	-	-	-	97.145	25.827	-	-	-	-
25-Mar-12	0.3	-	98.835	-	-	-	97.145	25.854	-	-	-	-
26-Mar-12	2.2	-	98.836	-	-	-	97.145	25.882	-	-	-	-
27-Mar-12	-2.3	-	98.836	-	-	-	97.145	25.909	-	-	-	-
28-Mar-12	3.9	-	98.837	-	-	-	97.146	25.937	-	-	-	-
29-Mar-12	2.8	-	98.838	-	-	-	97.146	25.965	-	-	-	-
30-Mar-12	1.2	-	98.839	-	-	-	97.146	25.992	-	-	-	-
31-Mar-12	4.9	-	98.840	-	-	-	97.147	26.020	-	-	-	-
01-Apr-12	-0.1	-	98.840	-	-	-	97.147	26.047	-	-	-	-
02-Apr-12	3.2	-	98.841	-	-	-	97.147	26.075	-	-	-	-
03-Apr-12	7.2	-	98.842	-	-	-	97.147	26.103	-	-	-	-
04-Apr-12	8.2	-	98.843	-	-	-	97.148	26.130	-	-	-	-
05-Apr-12	-0.8	-	98.843	-	-	-	97.148	26.158	-	-	-	-
06-Apr-12	-3.3	-	98.844	-	-	-	97.148	26.185	-	-	-	-
07-Apr-12	-4.5	-	98.845	-	-	-	97.149	26.213	-	-	-	-
08-Apr-12	-5.9	-	98.846	-	-	-	97.149	26.241	-	-	-	-
09-Apr-12	-3.9	-	98.846	-	-	-	97.149	26.268	-	-	-	-
10-Apr-12	1.3	-	98.847	-	-	-	97.149	26.296	-	-	-	-
11-Apr-12	7.2	-	98.848	-	-	-	97.150	26.323	-	-	-	-
12-Apr-12	7.1	-	98.849	-	-	-	97.150	26.351	-	-	-	-
13-Apr-12	4.7	-	98.849	-	-	-	97.150	26.379	-	-	-	-
14-Apr-12	-1.8	-	98.850	-	-	-	97.151	26.406	-	-	-	-
15-Apr-12	-6.4	-	98.851	-	-	-	97.151	26.434	-	-	-	-
16-Apr-12	-1.7	-	98.852	-	-	-	97.151	26.461	-	-	-	-
17-Apr-12	-4.2	-	98.853	-	-	-	97.152	26.489	-	-	-	-
18-Apr-12	0.1	-	98.853	-	-	-	97.152	26.517	-	-	-	-
19-Apr-12	5.3	-	98.854	-	-	-	97.152	26.544	-	-	-	-
20-Apr-12	7.9	-	98.855	-	-	-	97.152	26.572	-	-	-	-
21-Apr-12	7.4	-	98.856	-	-	-	97.153	26.599	-	-	-	-
22-Apr-12	8.9	-	98.856	-	-	-	97.153	26.627	-	-	-	-
23-Apr-12	6.0	-	98.857	-	-	-	97.153	26.654	-	-	-	-
24-Apr-12	2.7	-	98.858	-	-	-	97.154	26.682	-	-	-	-
25-Apr-12	2.3	-	98.859	-	-	-	97.154	26.710	-	2.216	-	-
26-Apr-12	5.6	-	98.859	-	-	-	97.154	26.737	-	2.112	-	-
27-Apr-12	4.1	-	98.860	-	-	-	97.154	26.765	-	1.976	-	-
28-Apr-12	10.1	-	98.861	-	-	-	97.155	26.792	-	1.864	-	-
29-Apr-12	10.8	-	98.862	-	-	-	97.155	26.820	-	1.779	-	-
30-Apr-12	7.7	-	98.863	-	-	-	97.155	26.848	-	1.677	-	-
01-May-12	10.1	-	98.863	-	-	-	97.156	26.875	-	1.571	-	-
02-May-12	10.0	0	98.864	-	-	-	97.156	26.903	-	1.489	-	-
03-May-12	12.3	0	98.865	-	-	-	97.156	26.930	-	1.374	-	-
04-May-12	9.3	0	98.866	-	-	-	97.156	26.958	-	1.270	-	-
05-May-12	11.2	0	98.866	-	-	-	97.157	26.986	-	1.169	-	-
06-May-12	9.1	0	98.867	-	-	-	97.157	27.013	-	1.078	-	-
07-May-12	11.9	0	98.868	-	-	-	97.157	27.041	-	0.995	-	-
08-May-12	18.2	0	98.869	-	-	-	97.158	27.068	-	0.926	-	-
09-May-12	11.3	3.2	98.869	-	-	-	97.158	27.096	-	0.861	-	-
10-May-12	7.7	0	98.848	0.036	-	-	97.142	25.911	-	0.787	-	-
11-May-12	7.1	0.4	98.822	0.027	98.407	0.060	97.126	24.696	98.976	0.732	-	-
12-May-12	12.9	0	98.828	0.030	98.462	0.076	97.122	24.334	98.975	0.685	-	-
13-May-12	11.8	0	98.819	0.027	98.475	0.081	97.110	23.495	98.975	0.650	-	-
14-May-12	10.3	1	98.811	0.025	98.472	0.080	97.099	22.671	98.966	0.607	-	-
15-May-12	11.9	0	98.815	0.027	98.552	0.108	97.094	22.257	98.956	0.568	-	-
16-May-12	13.3	0.2	98.810	0.026	98.469	0.079	97.081	21.324	98.960	0.554	-	-
17-May-12	9.7	7.4	98.805	0.025	98.382	0.054	97.065	20.220	98.962	0.524	-	-
18-May-12	5.7	1.4	98.943	0.108	98.490	0.086	97.072	20.589	99.016	0.511	-	-
19-May-12	5.2	4	98.909	0.080	98.495	0.088	97.078	20.960	99.009	0.655	-	-
20-May-12	8.2	0.6	98.982	0.153	98.541	0.104	97.122	23.805	99.026	0.721	-	-
21-May-12	12.1	0	98.962	0.133	98.557	0.110	97.164	26.679	99.043	0.895	-	-
22-May-12	13.9	0	98.931	0.103	98.480	0.084	97.179	27.687	99.059	0.895	-	-
23-May-12	10.7	0	98.908	0.086	98.415	0.063	97.175	27.304	99.050	0.877	-	-
24-May-12	11.2	0	98.881	0.068	98.438	0.071	97.164	26.417	99.050	0.886	-	-
25-May-12	10.4	0	98.868	0.061	98.506	0.093	97.149	25.332	99.041	0.859	-	-
26-May-12	14.5	0	98.846	0.050	98.488	0.087	97.128	23.787	99.033	0.785	-	-
27-May-12	18.6	0	98.835	0.045	98.454	0.076	97.105	22.156	99.014	0.730	-	-
28-May-12	16.4	0.2	98.817	0.038	98.426	0.067	97.082	20.582	98.999	0.674	-	-
29-May-12	18.6	0	98.805	0.034	98.430	0.069	97.060	19.125	98.987	0.616	-	-
30-May-12	18.7	0	98.797	0.032	98.386	0.056	97.036	17.602	98.976	0.562	-	-
31-May-12	16.1	0	98.786	0.029	98.357	0.048	97.011	16.139	98.959	0.510	-	-
01-Jun-12	15.4	0	98.775	0.025	98.310	0.037	96.988	14.793	98.953	0.453	-	-
02-Jun-12	15.8	0	98.766	0.023	98.297	0.034	96.974	13.976	98.950	0.406	-	-
03-Jun-12	13.4	4.2	98.760	0.022	98.266	0.028	96.956	12.976	98.930	0.400	-	-
04-Jun-12	12.9	0.6	98.779	0.029	98.386	0.057	96.947	12.459	98.991	0.388	-	-
05-Jun-12	14.3	0	98.775	0.028	98.475	0.084	96.941	12.101	98.973	0.471	-	-
06-Jun-12	19.9	0	98.779	0.030	98.467	0.081	96.937	11.893	98.962	0.431	-	-
07-Jun-12	21.3	0	98.765	0.026	98.402	0.061	96.933	11.639	98.944	0.388	-	-
08-Jun-12	17.9	0	98.747	0.021	98.374	0.054	96.920	10.960	98.921	0.350	-	-
09-Jun-12	16.6	0	98.738	0.020	98.323	0.041	96.905	10.209	98.901	0.310	-	-
10-Jun-12	12.9	0	98.730	0.018	98.298	0.035	96.895	9.705	98.895	0.266	-	-
11-Jun-12	12.1	0	98.727	0.018	98.397	0.061	96.882	9.084	98.882	0.231	-	-
12-Jun-12	13.2	0.4	98.727	0.018	98.372	0.054	96.878	8.904	98.880	0.197	-	-
13-Jun-12	15.8	0.2	98.725	0.018	98.329	0.043	96.870	8.516	98.921	0.183	-	-
14-Jun-12	13.7	1	98.724	0.019	98.288	0.033	96.868	8.382	98.965	0.158	-	-
15-Jun-12	11.2	0	98.727	0.020	98.350	0.048	96.881	8.877	99.018	0.134	-	-
16-Jun-12	12.4	6.2	98.720	0.019	98.407	0.064	96.895	9.429	99.059	0.118	-	-
17-Jun-12	14.0	10	98.716	0.018	98.290	0.034	96.898	9.508	99.087	0.098	-	-
18-Jun-12	13.8	22.2	98.760	0.032	98.254	0.027	96.930	10.955	99.113	0.076	-	-
19-Jun-12	12.8	5.8	99.339	1.736	98.392	0.060	97.070	18.428	99.155	0.061	-	-
20-Jun-12	13.3	0	99.242	1.117	98.480	0.088	97.232	29.400	99.184	0.044	-	-
21-Jun-12	16.0	0	99.157	0.731	98.513	0.099	97.309	35.422	99.271	0.035	-	-
22-Jun-12	19.4	0	99.121	0.603	98.474	0.086	97.326	36.745	99.332	0.028	-	-
23-Jun-12	16.1	0	99.060	0.427	98.440	0.075	97.313	35.553	99.362	0.036	-	-
24-Jun-12	18.9	0	99.030	0.359	98.473	0.086	97.287	33.406	99.361	0.039	-	-
25-Jun-12	19.5	2.2	99.003	0.303	98.392	0.061	97.246	30.083	99.346	0.039	-	-
26-Jun-12	20.1	0.2	98.985	0.273	98.328	0.044	97.215	27.660	99.378	0.052	-	-
27-Jun-12	16.4	9.4	98.952	0.220	98.250	0.027	97.168	24.219	99.370	0.077	-	-
28-Jun-12	18.5	0	99.013	0.337	98.254	0.027	97.122	21.063	99.343	0.079	-	-
29-Jun-12	17.0	0	98.991	0.296	98.318	0.042	97.087	18.787	99.342	0.061	-	-
30-Jun-12	21.2	0	98.937	0.206	98.321	0.043	97.051	16.637	99.347	0.070	-	-
01-Jul-12	17.2	9.4	98.881	0.135	98.284	0.034	97.021	14.885	99.333	0.046	-	-
02-Jul-12	19.5	0	98.948	0.229	98.313	0.041	97.019	14.710	99.344	0.029	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
03-Jul-12	18.7	7.4	98.935	0.212	98.295	0.037	97.090	18.735	99.336	0.030	-	-
04-Jul-12	14.1	37.2	98.935	0.214	98.239	0.025	97.165	23.500	99.363	0.032	-	-
05-Jul-12	17.3	0	99.494	not verified	98.508	0.099	97.347	37.362	99.459	0.028	-	-
06-Jul-12	17.4	0	99.261	not verified	98.559	0.119	97.593	61.107	99.520	0.028	-	-
07-Jul-12	20.1	0	99.163	0.895	98.576	0.125	97.659	68.295	99.568	0.027	-	-
08-Jul-12	21.1	1	99.100	0.644	98.566	0.122	97.705	73.490	99.620	0.031	-	-
09-Jul-12	25.5	0	99.052	0.496	98.504	0.099	97.698	72.524	99.626	0.025	-	-
10-Jul-12	22.9	5.2	98.989	0.340	98.445	0.079	97.656	67.542	99.573	0.022	-	-
11-Jul-12	22.0	0	99.016	0.407	98.498	0.097	97.631	64.604	99.553	0.044	-	-
12-Jul-12	18.8	0	99.141	0.840	98.464	0.085	97.616	62.927	99.538	0.090	-	-
13-Jul-12	16.1	0	99.061	0.549	98.512	0.102	97.563	57.126	99.539	0.065	-	-
14-Jul-12	21.5	0	98.993	0.366	98.510	0.102	97.503	50.903	99.554	0.053	-	-
15-Jul-12	15.6	0	98.908	0.208	98.450	0.081	97.434	44.190	99.526	0.044	-	-
16-Jul-12	17.6	0	98.869	0.157	98.485	0.093	97.377	38.970	99.504	0.034	-	-
17-Jul-12	22.5	0	98.845	0.131	98.405	0.067	97.327	34.640	99.480	0.030	-	-
18-Jul-12	19.2	4.8	98.790	0.083	98.337	0.049	97.272	30.249	99.443	0.028	-	-
19-Jul-12	15.2	10.6	98.810	0.101	98.320	0.044	97.239	27.717	99.421	0.027	-	-
20-Jul-12	18.9	0	99.140	0.899	98.450	0.082	97.243	28.007	99.420	0.026	-	-
21-Jul-12	20.2	0	98.996	0.400	98.425	0.074	97.238	27.632	-	0.019	-	-
22-Jul-12	19.8	0	98.954	0.305	98.380	0.061	97.206	25.318	-	0.012	-	-
23-Jul-12	19.6	0	98.904	0.217	98.388	0.063	97.183	23.715	-	0.009	-	-
24-Jul-12	18.0	0.6	98.861	0.158	98.346	0.051	97.155	21.832	-	0.012	-	-
25-Jul-12	20.5	0.2	98.851	0.145	98.344	0.051	97.133	20.404	-	0.016	-	-
26-Jul-12	20.8	0.4	98.995	0.405	98.388	0.063	97.121	19.643	-	0.022	-	-
27-Jul-12	21.3	0	98.899	0.212	98.358	0.055	97.098	18.227	-	0.025	-	-
28-Jul-12	22.2	0	98.861	0.160	98.316	0.044	97.076	16.921	-	0.026	-	-
29-Jul-12	16.3	1	98.839	0.135	98.323	0.045	97.064	16.226	-	0.035	-	-
30-Jul-12	23.5	0	98.826	0.121	98.315	0.043	97.044	15.103	-	0.059	-	-
31-Jul-12	20.1	0	98.811	0.107	98.262	0.031	97.025	14.071	-	0.084	-	-
01-Aug-12	18.0	0	98.784	0.084	98.295	0.039	97.006	13.075	-	0.110	-	-
02-Aug-12	16.4	1.2	98.770	0.075	98.270	0.033	97.007	13.122	-	0.127	-	-
03-Aug-12	18.7	0	98.766	0.072	98.334	0.048	97.046	15.196	-	0.148	-	-
04-Aug-12	21.2	0	98.791	0.092	98.309	0.042	97.078	17.006	-	0.167	-	-
05-Aug-12	18.3	0	98.765	0.073	98.273	0.034	97.044	15.077	-	0.166	-	-
06-Aug-12	18.1	0	98.762	0.070	98.303	0.041	97.024	13.993	-	0.181	-	-
07-Aug-12	21.8	0	98.757	0.068	98.312	0.043	97.011	13.308	-	0.187	-	-
08-Aug-12	22.7	0	98.751	0.064	98.331	0.048	96.992	12.339	-	0.169	-	-
09-Aug-12	19.1	1.2	98.755	0.067	98.264	0.032	96.986	12.038	-	0.168	-	-
10-Aug-12	21.4	0	98.755	0.068	98.255	0.030	96.968	11.162	-	0.157	-	-
11-Aug-12	14.8	0	98.744	0.061	98.253	0.030	96.953	10.457	-	0.145	-	-
12-Aug-12	18.0	0	98.737	0.057	98.308	0.042	96.938	9.774	-	0.150	-	-
13-Aug-12	15.1	7	98.734	0.055	98.319	0.045	96.930	9.417	-	0.179	-	-
14-Aug-12	13.4	0.4	98.747	0.064	98.216	0.022	96.934	9.590	-	0.192	-	-
15-Aug-12	14.7	0	98.735	0.057	98.345	0.052	96.935	9.630	-	0.191	-	-
16-Aug-12	21.5	0	98.751	0.067	98.281	0.036	96.959	10.717	-	0.155	-	-
17-Aug-12	20.4	0	98.725	0.052	98.261	0.031	96.943	9.980	-	0.124	-	-
18-Aug-12	21.5	0	98.705	0.042	98.317	0.044	96.933	9.532	-	0.113	-	-
19-Aug-12	24.8	0.2	98.673	0.029	98.259	0.031	96.943	9.973	-	0.100	-	-
20-Aug-12	19.8	0	98.610	0.013	98.249	0.029	96.918	8.876	-	0.084	-	-
21-Aug-12	24.1	0.6	98.578	0.008	98.214	0.022	96.907	8.411	-	0.074	-	-
22-Aug-12	16.8	13	98.542	0.004	98.201	0.020	96.903	8.242	-	0.078	-	-
23-Aug-12	16.9	2.2	98.579	0.008	98.204	0.020	96.908	8.446	-	0.093	-	-
24-Aug-12	15.5	0	98.757	0.074	98.189	0.018	96.943	9.956	-	0.099	-	-
25-Aug-12	14.2	3.8	98.743	0.065	98.199	0.020	96.967	11.060	-	0.107	-	-
26-Aug-12	17.6	0	98.753	0.072	98.268	0.033	96.987	12.022	-	0.245	-	-
27-Aug-12	21.4	0	98.750	0.070	98.301	0.041	96.995	12.415	-	0.315	-	-
28-Aug-12	21.2	0	98.751	0.071	98.229	0.025	97.008	13.070	-	0.372	-	-
29-Aug-12	16.8	0.2	98.743	0.066	98.181	0.017	97.006	12.963	-	0.421	-	-
30-Aug-12	12.5	0.4	98.750	0.071	98.185	0.017	97.009	13.113	-	0.505	-	-
31-Aug-12	14.6	0	98.725	0.056	98.303	0.041	96.996	12.449	-	0.571	-	-
01-Sep-12	14.3	0.6	98.724	0.056	98.298	0.040	96.988	12.048	-	0.617	-	-
02-Sep-12	14.2	24.8	98.693	0.040	98.184	0.017	96.983	11.799	-	0.627	-	-
03-Sep-12	10.6	22.4	98.798	0.112	98.331	0.048	97.025	13.931	-	0.633	-	-
04-Sep-12	13.0	6.2	99.299	not verified	98.460	0.087	97.120	19.387	-	0.921	-	-
05-Sep-12	14.2	0.4	99.242	1.658	98.499	0.100	97.239	27.442	-	1.477	-	-
06-Sep-12	14.9	0	99.223	1.522	98.530	0.112	97.367	37.605	-	2.019	-	-
07-Sep-12	14.1	1.6	99.186	1.287	98.473	0.091	97.402	40.647	-	2.437	-	-
08-Sep-12	15.1	0	99.143	1.049	98.610	0.143	97.404	40.818	-	2.652	-	-
09-Sep-12	16.6	0	99.089	0.795	98.438	0.080	97.413	41.615	-	2.748	-	-
10-Sep-12	12.4	18.4	99.056	0.669	98.310	0.043	97.416	41.877	-	2.817	-	-
11-Sep-12	7.0	53.4	99.261	1.825	98.436	0.079	97.452	45.172	-	2.786	-	-
12-Sep-12	8.0	0	99.941	not verified	98.792	0.228	97.749	76.953	-	2.780	-	-
13-Sep-12	13.1	0	99.742	not verified	98.806	0.236	98.145	131.953	-	2.732	-	-
14-Sep-12	17.8	0	99.551	not verified	98.802	0.234	98.143	131.627	-	2.646	-	-
15-Sep-12	8.7	0	99.401	not verified	98.730	0.198	98.143	131.615	-	2.616	-	-
16-Sep-12	9.1	0	99.257	1.815	98.853	0.261	98.093	123.877	-	2.568	-	-
17-Sep-12	14.7	0	99.187	1.327	98.754	0.209	98.024	113.577	-	2.469	-	-
18-Sep-12	12.3	1.8	99.127	0.995	98.563	0.125	97.924	99.423	-	2.378	-	-
19-Sep-12	10.0	0	99.075	0.760	98.657	0.164	97.848	89.276	-	2.273	-	-
20-Sep-12	10.1	0	99.026	0.583	98.639	0.156	97.762	78.453	-	2.158	-	-
21-Sep-12	12.4	0	98.977	0.436	98.625	0.150	97.697	70.720	-	2.060	-	-
22-Sep-12	18.5	0	98.941	0.350	98.621	0.149	97.621	62.171	-	1.955	-	-
23-Sep-12	17.4	0	98.927	0.319	98.598	0.139	97.559	55.591	-	1.844	-	-
24-Sep-12	16.3	0	98.910	0.287	98.561	0.124	97.507	50.345	-	1.745	-	-
25-Sep-12	12.4	0	98.885	0.243	98.519	0.108	97.461	45.913	-	1.656	-	-
26-Sep-12	11.2	0	98.876	0.227	98.543	0.117	97.416	41.765	-	1.544	-	-
27-Sep-12	16.9	0	98.870	0.219	98.566	0.126	97.385	39.016	-	1.454	-	-
28-Sep-12	21.7	0	98.877	0.230	98.466	0.090	97.361	36.949	-	1.361	-	-
29-Sep-12	12.7	2.2	98.848	0.188	98.383	0.063	97.311	32.823	-	1.266	-	-
30-Sep-12	9.2	0.2	98.849	0.190	98.454	0.086	97.272	29.767	-	1.168	-	-
01-Oct-12	5.2	7.2	98.838	0.175	98.508	0.104	97.253	28.328	-	1.097	-	-
02-Oct-12	4.3	0.6	98.849	0.192	98.434	0.079	97.231	26.706	-	1.032	-	-
03-Oct-12	4.6	0.8	98.870	0.224	98.629	0.152	97.228	26.483	-	0.973	-	-
04-Oct-12	5.5	0	98.867	0.220	98.698	0.183	97.236	27.058	-	0.936	-	-
05-Oct-12	5.5	0	98.854	0.202	98.672	0.171	97.232	26.761	-	0.877	-	-
06-Oct-12	6.1	0	98.867	0.222	98.561	0.125	97.239	27.266	-	0.838	-	-
07-Oct-12	7.9	0.8	98.848	0.194	98.479	0.094	97.216	25.602	-	0.794	-	-
08-Oct-12	3.6	0.2	98.853	0.201	98.495	0.100	97.210	25.173	-	0.754	-	-
09-Oct-12	2.0	0	98.845	0.191	98.543	0.118	97.207	24.956	-	0.724	-	-
10-Oct-12	-0.8	0.2	98.834	0.177	98.529	0.112	97.211	25.232	-	0.685	-	-
11-Oct-12	-1.8	0	98.841	0.187	98.643	0.159	97.216	25.580	-	0.649	-	-
12-Oct-12	-2.9	0	98.819	0.159	98.506	0.104	97.200	24.452	-	0.615	-	-
13-Oct-12	1.4	1.8	98.822	0.162	98.428	0.078	97.190	23.757	-	0.564	-	-
14-Oct-12	7.2	1	98.824	0.166	98.430	0.078	97.180	23.072	-	0.518	-	-
15-Oct-12	10.0	0	98.839	0.186	98.316	0.046	97.186	23.473	-	0.493	-	-
16-Oct-12	1.4	13.4	98.834	0.181	98.296	0.041	97.196	24.153	-	0.481	-	-
17-Oct-12	2.7	0.8	-	-	98.401	0.069	97.195	24.071	-	0.479	-	-
18-Oct-12	3.7	0	-	-	-	-	97.196	24.194	-	0.476	-	-
19-Oct-12	2.6	1	-	-	-	-	97.197	24.316	-	0.465	-	-
20-Oct-12	0.7	4	-	-	-	-	97.199	24.438	-	0.459	-	-
21-Oct-12	-1.2	0	-	-	-	-	97.200	24.560	-	0.453	-	-
22-Oct-12	-1.7	0	-	-	-	-	97.201	24.682	-	0.441	-	-
23-Oct-12	-0.9	0	-	-	-	-	97.202	24.804	-	0.440	-	-
24-Oct-12	-1.7	0.6	-	-	-	-	97.204	24.927	-	0.429	-	-
25-Oct-12	-3.4	0	-	-	-	-	97.205	25.049	-	0.416	-	-
26-Oct-12	-6.5	0	-	-	-	-	97.206	25.171	-	-	-	-
27-Oct-12	-8.8	0	-	-	-	-	97.208	25.293	-	-	-	-
28-Oct-12	-6.6	0	-	-	-	-	97.209	25.415	-	-	-	-
29-Oct-12	-8.0	0	-	-	-	-	97.210	25.537	-	-	-	-
30-Oct-12	-11.3	0	-	-	-	-	97.211	25.660	-	-	-	-
31-Oct-12	-10.3	0	-	-	-	-	97.213	25.782	-	-	-	-
01-Nov-12	-7.4	-	-	-	-	-	97.214	25.904	-	-	-	-
02-Nov-12	-6.9	-	-	-	-	-	97.215	26.026	-	-	-	-
03-Nov-12	-4.6	-	-	-	-	-	97.216	26.148	-	-	-	-
04-Nov-12	-0.9	-	-	-	-	-	97.218	26.270	-	-	-	-
05-Nov-12	4.1	-	-	-	-	-	97.219	26.393	-	-	-	-
06-Nov-12	-0.8	-	-	-	-	-	97.220	26.515	-	-	-	-
07-Nov-12	-5.5	-	-	-	-	-	97.221	26.637	-	-	-	-
08-Nov-12	-11.4	-	-	-	-	-	97.223	26.759	-	-	-	-
09-Nov-12	-19.1	-	-	-	-	-	97.224	26.881	-	-	-	-
10-Nov-12	-12.5	-	-	-	-	-	97.225	27.003	-	-	-	-
11-Nov-12	-9.1	-	-	-	-	-	97.226	27.126	-	-	-	-
12-Nov-12	-8.6	-	-	-	-	-	97.228	27.248	-	-	-	-
13-Nov-12	-10.6	-	-	-	-	-	97.229	27.370	-	-	-	-
14-Nov-12	-14.2	-	-	-	-	-	97.230	27.492	-	-	-	-
15-Nov-12	-9.1	-	-	-	-	-	97.232	27.614	-	-	-	-
16-Nov-12	-8.6	-	-	-	-	-	97.233	27.737	-	-	-	-
17-Nov-12	-4.6	-	-	-	-	-	97.234	27.859	-	-	-	-
18-Nov-12	-5.6	-	-	-	-	-	97.235	27.981	-	-	-	-
19-Nov-12	-12.1	-	-	-	-	-	97.237	28.103	-	-	-	-
20-Nov-12	-15.8	-	-	-	-	-	97.238	28.225	-	-	-	-
21-Nov-12	-16.0	-	-	-	-	-	97.239	28.347	-	-	-	-
22-Nov-12	-17.6	-	-	-	-	-	97.240	28.470	-	-	-	-
23-Nov-12	-17.2	-	-	-	-	-	97.242	28.592	-	-	-	-
24-Nov-12	-14.8	-	-	-	-	-	97.243	28.714	-	-	-	-
25-Nov-12	-17.3	-	-	-	-	-	97.244	28.836	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
26-Nov-12	-19.0	-	-	-	-	-	97.245	28.958	-	-	-	-
27-Nov-12	-18.5	-	-	-	-	-	97.247	29.080	-	-	-	-
28-Nov-12	-24.7	-	-	-	-	-	97.248	29.203	-	-	-	-
29-Nov-12	-26.5	-	-	-	-	-	97.249	29.325	-	-	-	-
30-Nov-12	-17.2	-	-	-	-	-	97.251	29.447	-	-	-	-
01-Dec-12	-21.2	-	-	-	-	-	97.252	29.569	-	-	-	-
02-Dec-12	-18.0	-	-	-	-	-	97.253	29.691	-	-	-	-
03-Dec-12	-18.8	-	-	-	-	-	97.254	29.813	-	-	-	-
04-Dec-12	-12.5	-	-	-	-	-	97.256	29.936	-	-	-	-
05-Dec-12	-12.9	-	-	-	-	-	97.257	30.058	-	-	-	-
06-Dec-12	-17.2	-	-	-	-	-	97.258	30.180	-	-	-	-
07-Dec-12	-18.1	-	-	-	-	-	97.259	30.302	-	-	-	-
08-Dec-12	-25.5	-	-	-	-	-	97.261	30.424	-	-	-	-
09-Dec-12	-20.5	-	-	-	-	-	97.262	30.546	-	-	-	-
10-Dec-12	-27.5	-	-	-	-	-	97.263	30.669	-	-	-	-
11-Dec-12	-20.9	-	-	-	-	-	97.264	30.791	-	-	-	-
12-Dec-12	-27.5	-	-	-	-	-	97.266	30.913	-	-	-	-
13-Dec-12	-15.2	-	-	-	-	-	97.267	31.035	-	-	-	-
14-Dec-12	-7.6	-	-	-	-	-	97.268	31.157	-	-	-	-
15-Dec-12	-10.8	-	-	-	-	-	97.269	31.279	-	-	-	-
16-Dec-12	-7.2	-	-	-	-	-	97.271	31.402	-	-	-	-
17-Dec-12	-14.8	-	-	-	-	-	97.272	31.524	-	-	-	-
18-Dec-12	-16.0	-	-	-	-	-	97.273	31.646	-	-	-	-
19-Dec-12	-17.9	-	-	-	-	-	97.275	31.768	-	-	-	-
20-Dec-12	-21.3	-	-	-	-	-	97.276	31.890	-	-	-	-
21-Dec-12	-15.3	-	-	-	-	-	97.277	32.012	-	-	-	-
22-Dec-12	-25.0	-	-	-	-	-	97.278	32.135	-	-	-	-
23-Dec-12	-33.3	-	-	-	-	-	97.280	32.257	-	-	-	-
24-Dec-12	-28.4	-	-	-	-	-	97.281	32.379	-	-	-	-
25-Dec-12	-26.3	-	-	-	-	-	97.282	32.501	-	-	-	-
26-Dec-12	-31.1	-	-	-	-	-	97.283	32.623	-	-	-	-
27-Dec-12	-28.9	-	-	-	-	-	97.285	32.745	-	-	-	-
28-Dec-12	-22.4	-	-	-	-	-	97.286	32.868	-	-	-	-
29-Dec-12	-20.2	-	-	-	-	-	97.287	32.990	-	-	-	-
30-Dec-12	-23.1	-	-	-	-	-	97.288	33.112	-	-	-	-
31-Dec-12	-11.5	-	-	-	-	-	97.290	33.234	-	-	-	-
01-Jan-13	-5.0	-	-	-	-	-	97.291	33.356	-	-	-	-
02-Jan-13	-7.1	-	-	-	-	-	97.292	33.478	-	-	-	-
03-Jan-13	-1.9	-	-	-	-	-	97.293	33.601	-	-	-	-
04-Jan-13	-10.4	-	-	-	-	-	97.295	33.723	-	-	-	-
05-Jan-13	-7.4	-	-	-	-	-	97.296	33.845	-	-	-	-
06-Jan-13	-7.9	-	-	-	-	-	97.297	33.967	-	-	-	-
07-Jan-13	-7.6	-	-	-	-	-	97.299	34.089	-	-	-	-
08-Jan-13	-12.1	-	-	-	-	-	97.300	34.211	-	-	-	-
09-Jan-13	-13.9	-	-	-	-	-	97.301	34.334	-	-	-	-
10-Jan-13	-23.1	-	-	-	-	-	97.302	34.456	-	-	-	-
11-Jan-13	-15.3	-	-	-	-	-	97.304	34.578	-	-	-	-
12-Jan-13	-19.0	-	-	-	-	-	97.305	34.700	-	-	-	-
13-Jan-13	-26.3	-	-	-	-	-	97.306	34.822	-	-	-	-
14-Jan-13	-12.9	-	-	-	-	-	97.307	34.944	-	-	-	-
15-Jan-13	-14.7	-	-	-	-	-	97.309	35.067	-	-	-	-
16-Jan-13	-22.1	-	-	-	-	-	97.310	35.189	-	-	-	-
17-Jan-13	-19.0	-	-	-	-	-	97.311	35.311	-	-	-	-
18-Jan-13	-18.5	-	-	-	-	-	97.312	35.433	-	-	-	-
19-Jan-13	-27.2	-	-	-	-	-	97.314	35.555	-	-	-	-
20-Jan-13	-28.4	-	-	-	-	-	97.315	35.677	-	-	-	-
21-Jan-13	-26.9	-	-	-	-	-	97.316	35.800	-	-	-	-
22-Jan-13	-23.8	-	-	-	-	-	97.317	35.922	-	-	-	-
23-Jan-13	-25.5	-	-	-	-	-	97.319	36.044	-	-	-	-
24-Jan-13	-18.5	-	-	-	-	-	97.320	36.166	-	-	-	-
25-Jan-13	-17.2	-	-	-	-	-	97.321	36.288	-	-	-	-
26-Jan-13	-14.2	-	-	-	-	-	97.323	36.410	-	-	-	-
27-Jan-13	-15.5	-	-	-	-	-	97.324	36.533	-	-	-	-
28-Jan-13	-23.0	-	-	-	-	-	97.325	36.655	-	-	-	-
29-Jan-13	-30.1	-	-	-	-	-	97.326	36.777	-	-	-	-
30-Jan-13	-31.7	-	-	-	-	-	97.328	36.899	-	-	-	-
31-Jan-13	-25.3	-	-	-	-	-	97.329	37.021	-	-	-	-
01-Feb-13	-21.4	-	-	-	-	-	97.330	37.143	-	-	-	-
02-Feb-13	-21.1	-	-	-	-	-	97.331	37.266	-	-	-	-
03-Feb-13	-18.0	-	-	-	-	-	97.333	37.388	-	-	-	-
04-Feb-13	-13.8	-	-	-	-	-	97.334	37.510	-	-	-	-
05-Feb-13	-16.4	-	-	-	-	-	97.335	37.632	-	-	-	-
06-Feb-13	-15.4	-	-	-	-	-	97.336	37.754	-	-	-	-
07-Feb-13	-9.2	-	-	-	-	-	97.338	37.876	-	-	-	-
08-Feb-13	-3.8	-	-	-	-	-	97.339	37.999	-	-	-	-
09-Feb-13	-7.4	-	-	-	-	-	97.340	38.121	-	-	-	-
10-Feb-13	-9.4	-	-	-	-	-	97.342	38.243	-	-	-	-
11-Feb-13	1.0	-	-	-	-	-	97.343	38.365	-	-	-	-
12-Feb-13	-2.1	-	-	-	-	-	97.344	38.487	-	-	-	-
13-Feb-13	-10.6	-	-	-	-	-	97.345	38.609	-	-	-	-
14-Feb-13	-8.7	-	-	-	-	-	97.347	38.732	-	-	-	-
15-Feb-13	-1.9	-	-	-	-	-	97.348	38.854	-	-	-	-
16-Feb-13	1.9	-	-	-	-	-	97.349	38.976	-	-	-	-
17-Feb-13	-12.3	-	-	-	-	-	97.350	39.098	-	-	-	-
18-Feb-13	-13.5	-	-	-	-	-	97.352	39.220	-	-	-	-
19-Feb-13	-13.5	-	-	-	-	-	97.353	39.342	-	-	-	-
20-Feb-13	-11.1	-	-	-	-	-	97.354	39.465	-	-	-	-
21-Feb-13	-6.5	-	-	-	-	-	97.355	39.587	-	-	-	-
22-Feb-13	-5.8	-	-	-	-	-	97.357	39.709	-	-	-	-
23-Feb-13	-6.3	-	-	-	-	-	97.358	39.831	-	-	-	-
24-Feb-13	-4.5	-	-	-	-	-	97.359	39.953	-	-	-	-
25-Feb-13	-6.6	-	-	-	-	-	97.360	40.075	-	-	-	-
26-Feb-13	-10.3	-	-	-	-	-	97.362	40.198	-	-	-	-
27-Feb-13	-3.0	-	-	-	-	-	97.363	40.320	-	-	-	-
28-Feb-13	-1.0	-	-	-	-	-	97.364	40.442	-	-	-	-
01-Mar-13	1.6	-	-	-	-	-	97.366	40.564	-	-	-	-
02-Mar-13	1.2	-	-	-	-	-	97.367	40.686	-	-	-	-
03-Mar-13	-5.4	-	-	-	-	-	97.368	40.808	-	-	-	-
04-Mar-13	-9.9	-	-	-	-	-	97.369	40.931	-	-	-	-
05-Mar-13	-5.9	-	-	-	-	-	97.371	41.053	-	-	-	-
06-Mar-13	-13.8	-	-	-	-	-	97.372	41.175	-	-	-	-
07-Mar-13	-18.5	-	-	-	-	-	97.373	41.297	-	-	-	-
08-Mar-13	-8.3	-	-	-	-	-	97.374	41.419	-	-	-	-
09-Mar-13	-9.4	-	-	-	-	-	97.376	41.541	-	-	-	-
10-Mar-13	-4.0	-	-	-	-	-	97.377	41.664	-	-	-	-
11-Mar-13	-9.2	-	-	-	-	-	97.378	41.786	-	-	-	-
12-Mar-13	-11.6	-	-	-	-	-	97.379	41.908	-	-	-	-
13-Mar-13	-18.7	-	-	-	-	-	97.381	42.030	-	-	-	-
14-Mar-13	-21.6	-	-	-	-	-	97.382	42.152	-	-	-	-
15-Mar-13	-22.1	-	-	-	-	-	97.383	42.274	-	-	-	-
16-Mar-13	-23.7	-	-	-	-	-	97.384	42.397	-	-	-	-
17-Mar-13	-19.7	-	-	-	-	-	97.386	42.519	-	-	-	-
18-Mar-13	-19.6	-	-	-	-	-	97.387	42.641	-	-	-	-
19-Mar-13	-12.7	-	-	-	-	-	97.388	42.763	-	-	-	-
20-Mar-13	-6.6	-	-	-	-	-	97.390	42.885	-	-	-	-
21-Mar-13	-6.9	-	-	-	-	-	97.391	43.007	-	-	-	-
22-Mar-13	-7.7	-	-	-	-	-	97.392	43.130	-	-	-	-
23-Mar-13	-9.2	-	-	-	-	-	97.393	43.252	-	-	-	-
24-Mar-13	-8.5	-	-	-	-	-	97.395	43.374	-	-	-	-
25-Mar-13	-4.1	-	-	-	-	-	97.396	43.496	-	-	-	-
26-Mar-13	-3.3	-	-	-	-	-	97.397	43.618	-	-	-	-
27-Mar-13	2.7	-	-	-	-	-	97.398	43.740	-	-	-	-
28-Mar-13	-0.6	-	-	-	-	-	97.400	43.863	-	-	-	-
29-Mar-13	-1.3	-	-	-	-	-	97.401	43.985	-	-	-	-
30-Mar-13	-6.2	-	-	-	-	-	97.402	44.107	-	-	-	-
31-Mar-13	-2.5	-	-	-	-	-	97.403	44.229	-	-	-	-
01-Apr-13	-3.3	-	-	-	-	-	97.405	44.351	-	-	-	-
02-Apr-13	3.7	-	-	-	-	-	97.406	44.473	-	-	-	-
03-Apr-13	-3.3	-	-	-	-	-	97.407	44.596	-	-	-	-
04-Apr-13	-5.5	-	-	-	-	-	97.408	44.718	-	-	-	-
05-Apr-13	-9.0	-	-	-	-	-	97.410	44.840	-	-	-	-
06-Apr-13	-6.4	-	-	-	-	-	97.411	44.962	-	-	-	-
07-Apr-13	-9.3	-	-	-	-	-	97.412	45.084	-	-	-	-
08-Apr-13	-6.7	-	-	-	-	-	97.414	45.206	-	-	-	-
09-Apr-13	1.9	-	-	-	-	-	97.415	45.329	-	-	-	-
10-Apr-13	2.4	-	-	-	-	-	97.416	45.451	-	-	-	-
11-Apr-13	2.4	-	-	-	-	-	97.417	45.573	-	-	-	-
12-Apr-13	3.7	-	-	-	-	-	97.419	45.695	-	-	-	-
13-Apr-13	-0.8	-	-	-	-	-	97.420	45.817	-	-	-	-
14-Apr-13	4.1	-	-	-	-	-	97.421	45.939	-	-	-	-
15-Apr-13	1.2	-	-	-	-	-	97.422	46.062	-	-	-	-
16-Apr-13	1.2	-	-	-	-	-	97.424	46.184	-	-	-	-
17-Apr-13	4.2	-	-	-	-	-	97.425	46.306	-	-	-	-
18-Apr-13	2.4	-	98.245	0.000	-	-	97.426	46.428	-	-	-	-
19-Apr-13	1.7	-	98.249	0.000	-	-	97.427	46.550	99.166	-	-	-
20-Apr-13	-1.0	-	98.244	0.000	-	-	97.429	46.672	99.202	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
21-Apr-13	-2.9	-	98.210	0.000	-	-	97.430	46.795	99.322	-	-	-
22-Apr-13	2.1	-	98.182	0.000	-	-	97.431	46.917	99.305	-	-	-
23-Apr-13	-0.9	-	98.182	0.000	-	-	97.433	47.039	99.286	-	-	-
24-Apr-13	2.6	-	98.351	0.000	-	-	97.434	47.161	99.276	-	-	-
25-Apr-13	6.1	-	98.531	0.000	-	-	97.435	47.283	99.294	-	-	-
26-Apr-13	0.1	-	98.546	0.000	-	-	97.436	47.405	99.329	-	-	-
27-Apr-13	4.7	-	98.494	0.000	-	-	97.438	47.528	99.327	-	-	-
28-Apr-13	-3.2	-	98.562	0.000	-	-	97.439	47.650	99.369	-	-	-
29-Apr-13	-4.6	-	98.591	0.000	-	-	97.440	47.772	99.514	-	-	-
30-Apr-13	-4.9	-	98.650	0.000	-	-	97.441	47.894	99.488	-	-	-
01-May-13	-1.3	0	98.580	0.000	-	-	97.443	48.016	99.464	-	-	-
02-May-13	9.1	0	98.501	0.000	-	-	97.444	48.138	99.406	-	-	-
03-May-13	10.7	0	98.611	0.000	-	-	97.445	48.261	99.429	-	-	-
04-May-13	12.5	0	98.712	0.000	-	-	97.446	48.383	99.455	0.939	-	-
05-May-13	15.9	0	99.061	0.075	-	-	97.448	48.505	99.481	1.074	-	-
06-May-13	10.9	2.6	99.136	0.149	-	-	97.449	48.627	99.518	1.322	-	-
07-May-13	3.0	0.4	98.978	0.034	-	-	97.450	48.749	99.576	1.343	-	-
08-May-13	3.3	0.6	98.869	0.008	-	-	97.451	48.871	99.629	1.278	-	-
09-May-13	6.0	2	98.752	0.000	-	-	97.453	48.994	99.626	1.212	-	-
10-May-13	4.4	0.2	98.748	0.000	-	-	97.454	49.116	99.601	1.165	-	-
11-May-13	12.5	0	98.745	0.000	-	-	97.455	49.238	99.578	1.124	-	-
12-May-13	17.2	4	98.746	0.000	-	-	97.457	49.360	99.565	1.080	-	-
13-May-13	14.3	0	98.866	0.010	-	-	97.458	49.482	99.564	1.034	-	-
14-May-13	9.0	0	98.931	0.026	-	-	97.459	49.604	99.584	0.961	-	-
15-May-13	12.1	0	98.838	0.027	-	-	97.460	49.727	99.585	0.891	-	-
16-May-13	13.6	0	98.742	0.029	-	-	97.462	49.849	99.584	0.863	-	-
17-May-13	14.5	0	98.687	0.049	-	-	97.463	49.971	99.579	0.793	-	-
18-May-13	18.8	0	98.623	0.070	-	-	97.464	50.093	99.553	0.727	-	-
19-May-13	20.1	0	98.576	0.115	-	-	97.465	50.215	99.538	0.673	-	-
20-May-13	15.8	0	98.548	0.121	-	-	97.467	50.337	99.533	0.615	-	-
21-May-13	17.3	0	98.504	0.083	-	-	97.468	50.460	99.517	0.571	-	-
22-May-13	18.8	0	98.460	0.053	-	-	97.469	50.582	99.494	0.494	-	-
23-May-13	19.4	0	98.422	0.036	-	-	97.470	50.704	99.469	0.447	-	-
24-May-13	19.3	0	98.405	0.029	-	-	97.472	50.826	99.450	0.403	-	-
25-May-13	13.9	0	98.383	0.022	-	-	97.473	50.948	99.435	0.364	-	-
26-May-13	13.3	1.4	98.355	0.015	-	-	97.474	51.070	99.422	0.332	-	-
27-May-13	15.9	0.6	98.384	0.023	-	-	97.475	51.193	99.394	0.307	-	-
28-May-13	16.9	0	98.336	0.012	-	-	97.477	51.315	99.374	0.286	-	-
29-May-13	16.1	0.4	98.327	0.010	-	-	97.478	51.437	99.369	0.260	-	-
30-May-13	19.1	0	98.324	0.010	-	-	97.479	51.559	99.358	0.238	-	-
31-May-13	18.2	0	98.326	0.010	-	-	97.481	51.681	99.343	0.214	-	-
01-Jun-13	18.1	5.4	98.307	0.007	-	-	97.482	51.803	99.323	0.199	-	-
02-Jun-13	17.9	0	98.314	0.008	-	-	97.483	51.926	99.315	0.206	-	-
03-Jun-13	18.3	0	98.402	0.028	-	-	97.484	52.048	99.301	0.182	-	-
04-Jun-13	20.6	0	98.300	0.006	-	-	97.486	52.170	99.288	0.167	-	-
05-Jun-13	17.9	3.2	98.291	0.006	-	-	97.487	52.292	99.265	0.185	-	-
06-Jun-13	14.7	16.4	98.295	0.006	-	-	97.488	52.414	99.255	0.203	-	-
07-Jun-13	15.8	0	98.509	0.054	-	-	97.489	52.536	99.322	0.174	-	-
08-Jun-13	10.3	31	98.433	0.027	-	-	97.491	52.659	99.327	0.147	-	-
09-Jun-13	8.3	49	99.040	0.064	-	-	97.492	52.781	99.412	0.129	-	-
10-Jun-13	8.6	10.8	99.521	0.094	-	-	97.493	52.903	99.552	0.117	-	-
11-Jun-13	11.1	8.2	99.417	0.159	-	-	97.494	53.025	99.951	0.106	-	-
12-Jun-13	13.8	1.2	99.286	0.420	-	-	97.496	53.147	99.938	0.081	-	-
13-Jun-13	17.0	2.2	99.056	0.310	-	-	97.497	53.269	99.854	0.064	-	-
14-Jun-13	15.7	0.4	98.895	0.193	-	-	97.498	53.392	99.787	0.056	-	-
15-Jun-13	14.0	10.2	98.881	0.161	-	-	97.499	53.514	99.720	0.060	-	-
16-Jun-13	16.2	0	98.988	0.154	-	-	97.501	53.636	99.691	0.058	-	-
17-Jun-13	16.1	2	98.808	0.098	-	-	97.502	53.758	99.678	0.049	-	-
18-Jun-13	16.2	0.2	98.715	0.067	-	-	97.503	53.880	99.656	0.037	-	-
19-Jun-13	17.6	0	98.629	0.039	-	-	97.505	54.002	99.621	0.029	-	-
20-Jun-13	19.3	0	98.563	0.024	-	-	97.506	54.125	99.581	0.024	-	-
21-Jun-13	19.3	0	98.518	0.016	-	-	97.507	54.247	99.550	0.020	-	-
22-Jun-13	18.3	0	98.495	0.011	-	-	97.508	54.369	99.527	0.012	-	-
23-Jun-13	17.2	1	98.477	0.009	-	-	97.510	54.491	99.501	0.008	-	-
24-Jun-13	15.9	6.4	98.465	0.007	-	-	97.511	54.613	99.469	0.014	-	-
25-Jun-13	18.3	2.2	98.496	0.012	-	-	97.512	54.735	99.458	0.018	-	-
26-Jun-13	19.8	0	98.480	0.009	-	-	97.513	54.858	99.441	0.012	-	-
27-Jun-13	17.4	7.4	98.465	0.007	-	-	97.515	54.980	99.426	0.010	-	-
28-Jun-13	19.9	0.2	98.490	0.011	-	-	97.516	55.102	99.415	0.011	-	-
29-Jun-13	19.6	2	98.505	0.013	-	-	97.517	55.224	99.407	0.011	-	-
30-Jun-13	22.2	0	98.492	0.011	-	-	97.518	55.346	99.399	0.012	-	-
01-Jul-13	25.1	0	98.532	0.019	-	-	97.520	55.468	99.383	0.014	-	-
02-Jul-13	26.3	0	98.501	0.012	-	-	97.521	55.591	99.366	0.016	-	-
03-Jul-13	21.8	0	98.478	0.009	-	-	97.522	55.713	99.346	0.023	-	-
04-Jul-13	18.0	0	98.461	0.007	-	-	97.524	55.835	99.330	0.019	-	-
05-Jul-13	15.4	5.6	98.450	0.005	-	-	97.525	55.957	99.309	0.016	-	-
06-Jul-13	14.6	3.4	98.457	0.006	-	-	97.526	56.079	99.306	0.018	-	-
07-Jul-13	15.8	2.2	98.472	0.008	-	-	97.527	56.201	99.299	0.027	-	-
08-Jul-13	17.0	5.4	98.475	0.008	-	-	97.529	56.324	99.285	0.058	-	-
09-Jul-13	19.1	0.2	98.498	0.012	-	-	97.530	56.446	99.287	0.085	-	-
10-Jul-13	20.8	0	98.503	0.013	-	-	97.531	56.568	99.282	0.067	-	-
11-Jul-13	16.1	16.2	98.498	0.012	-	-	97.532	56.690	99.277	0.055	-	-
12-Jul-13	10.5	17	98.611	0.012	-	-	97.534	56.812	99.299	0.039	-	-
13-Jul-13	9.9	0.6	98.989	0.011	-	-	97.535	56.934	99.335	0.029	-	-
14-Jul-13	13.6	0	98.807	0.010	-	-	97.536	57.057	99.376	0.023	-	-
15-Jul-13	13.9	0	98.741	0.003	-	-	97.537	57.179	99.418	0.022	-	-
16-Jul-13	12.7	0	98.706	0.001	-	-	97.539	57.301	99.440	0.026	-	-
17-Jul-13	17.0	0	98.699	0.001	-	-	97.540	57.423	99.436	0.045	-	-
18-Jul-13	17.2	0	98.774	0.006	-	-	97.541	57.545	99.424	0.047	-	-
19-Jul-13	14.2	0	98.840	0.017	-	-	97.542	57.667	99.407	0.029	-	-
20-Jul-13	16.3	0	98.838	0.016	-	-	97.544	57.790	99.389	0.031	-	-
21-Jul-13	17.5	0	98.918	0.043	-	-	97.545	57.912	99.363	0.035	-	-
22-Jul-13	12.7	0	98.914	0.041	-	-	97.546	58.034	99.347	0.031	-	-
23-Jul-13	-	-	98.896	0.034	-	-	97.548	58.156	99.338	0.032	-	-
24-Jul-13	-	0	98.891	0.032	-	-	97.549	58.278	99.340	0.035	-	-
25-Jul-13	-	0.2	98.853	0.020	98.429	-	97.550	58.401	99.331	0.043	-	-
26-Jul-13	-	0	98.819	0.012	98.422	0.075	97.551	58.523	99.319	0.031	-	-
27-Jul-13	-	0.4	98.782	0.007	98.398	0.067	97.553	58.645	99.303	0.037	-	-
28-Jul-13	-	1.4	98.746	0.003	98.403	0.068	97.554	58.767	99.296	0.030	-	-
29-Jul-13	-	0.2	98.819	0.012	98.395	0.066	97.555	58.889	99.345	0.027	-	-
30-Jul-13	-	0.2	98.881	0.028	98.394	0.065	97.556	59.011	99.332	0.021	-	-
31-Jul-13	-	0.2	98.987	0.085	98.390	0.064	97.558	59.134	99.323	0.020	-	-
01-Aug-13	-	0.2	98.943	0.056	98.389	0.063	97.559	59.256	99.329	0.015	-	-
02-Aug-13	-	0.2	98.935	0.051	98.376	0.060	97.560	59.378	99.334	0.010	-	-
03-Aug-13	-	0	98.885	0.029	98.357	0.054	97.561	59.500	99.336	0.008	-	-
04-Aug-13	-	0	98.815	0.012	98.381	0.060	97.563	59.622	99.328	0.004	-	-
05-Aug-13	-	0	98.802	0.009	98.373	0.058	97.564	59.744	99.325	0.004	-	-
06-Aug-13	-	0	98.799	0.009	98.356	0.053	97.565	59.867	99.317	0.007	-	-
07-Aug-13	-	0	98.792	0.008	98.345	0.050	97.566	59.989	99.321	0.012	-	-
08-Aug-13	-	-	98.784	0.007	98.331	0.046	97.568	60.111	99.321	0.016	-	-
09-Aug-13	-	-	98.772	0.006	98.323	0.044	97.569	60.233	99.307	0.012	-	-
10-Aug-13	-	-	98.775	0.006	98.322	0.044	97.570	60.355	99.304	0.011	-	-
11-Aug-13	-	-	98.768	0.005	98.309	0.040	97.572	60.477	99.297	0.009	-	-
12-Aug-13	-	-	98.764	0.005	98.302	0.039	97.573	60.600	99.293	0.013	-	-
13-Aug-13	-	-	98.757	0.004	98.306	0.039	97.574	60.722	99.276	0.011	-	-
14-Aug-13	-	-	98.753	0.004	98.303	0.038	97.575	60.844	99.266	0.014	-	-
15-Aug-13	-	-	98.962	0.000	98.469	0.085	97.577	60.966	99.283	0.014	-	-
16-Aug-13	-	-	99.146	0.002	98.377	0.057	97.578	61.088	99.267	0.014	-	-
17-Aug-13	-	-	99.133	0.005	98.388	0.060	97.579	61.210	99.267	0.014	-	-
18-Aug-13	-	-	99.159	0.008	98.353	0.050	97.580	61.333	99.261	0.013	-	-
19-Aug-13	-	-	99.106	0.003	98.323	0.042	97.582	61.455	99.259	0.010	-	-
20-Aug-13	-	-	99.131	0.005	98.313	0.040	97.583	61.577	99.258	0.012	-	-
21-Aug-13	-	-	99.104	0.003	98.302	0.037	97.584	61.699	99.255	0.012	-	-
22-Aug-13	-	-	99.089	0.002	98.298	0.036	97.585	61.821	99.232	0.012	-	-
23-Aug-13	-	-	99.053	0.000	98.300	0.036	97.587	61.943	99.222	0.012	-	-
24-Aug-13	-	-	99.041	0.000	98.301	0.036	97.588	62.066	99.204	0.012	-	-
25-Aug-13	-	-	99.069	0.001	98.299	0.036	97.589	62.188	99.201	0.010	-	-
26-Aug-13	-	-	99.118	0.004	98.309	0.038	97.590	62.310	99.220	0.009	-	-
27-Aug-13	-	-	99.148	0.007	98.311	0.038	97.592	62.432	99.209	0.007	-	-
28-Aug-13	-	-	99.193	0.014	98.327	0.042	97.593	62.554	99.269	0.011	-	-
29-Aug-13	-	-	99.197	0.014	98.321	0.040	97.594	62.676	99.258	0.017	-	-
30-Aug-13	-	-	99.278	0.040	98.338	0.044	97.596	62.799	99.253	0.016	-	-
31-Aug-13	-	-	99.217	0.019	98.344	0.045	97.597	62.921	99.253	0.014	-	-
01-Sep-13	-	-	99.214	0.018	98.342	0.045	97.598	63.043	99.258	0.014	-	-
02-Sep-13	-	-	99.233	0.023	98.339	0.044	97.599	63.165	99.259	0.014	-	-
03-Sep-13	-	-	99.195	0.014	98.338	0.043	97.601	63.287	99.259	0.012	-	-
04-Sep-13	-	-	99.168	0.009	98.326	0.040	97.602	63.409	99.252	0.012	-	-
05-Sep-13	-	-	99.160	0.008	98.333	0.042	97.603	63.532	99.256	0.011	-	-
06-Sep-13	-	-	99.096	0.002	98.336	0.042	97.604	63.654	99.269	0.010	-	-
07-Sep-13	-	-	99.086	0.002	98.344	0.044	97.606	63.776	99.284	0.010	-	-
08-Sep-13	-	-	99.055	0.000	98.330	0.041	97.607	63.898	99.274	0.010	-	-
09-Sep-13	-	-	99.048	0.000	98.332	0.041	97.608	64.020	99.290	0.011	-	-
10-Sep-13	-	-	99.030	0.000	98.335	0.041	97.609	64.142	99.307	0.011	-	-
11-Sep-13	-	-	99.012	0.000	98.338	0.042	97.611	64.265	99.323	0.012	-	-
12-Sep-13	-	-	98.985	0.000	98.329	0.040	97.612	64.387	99.314	0.013	-	-
13-Sep-13	-	-	98.962	0.000	98.338	0.042	97.613	64.509	99.313	0.011	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
14-Sep-13	-	-	98.967	0.000	98.350	0.044	97.615	64.631	99.332	0.011	-	-
15-Sep-13	-	-	98.968	0.000	98.348	0.044	97.616	64.753	99.331	0.011	-	-
16-Sep-13	-	-	98.951	0.000	98.351	0.044	97.617	64.875	99.327	0.017	-	-
17-Sep-13	-	-	98.955	0.000	98.354	0.045	97.618	64.998	99.330	0.026	-	-
18-Sep-13	-	-	99.026	0.000	98.465	0.076	97.620	65.120	99.334	0.027	-	-
19-Sep-13	-	-	99.135	0.005	98.483	0.081	97.621	65.242	99.354	0.029	-	-
20-Sep-13	-	-	99.097	0.003	98.448	0.070	97.622	65.364	99.343	0.028	-	-
21-Sep-13	-	-	99.222	0.020	98.432	0.065	97.623	65.486	99.334	0.032	-	-
22-Sep-13	-	-	99.214	0.018	98.414	0.060	97.625	65.608	99.343	0.032	-	-
23-Sep-13	-	-	99.260	0.032	98.446	0.069	97.626	65.731	99.349	0.032	-	-
24-Sep-13	-	-	99.261	0.033	98.423	0.062	97.627	65.853	99.346	0.031	-	-
25-Sep-13	-	-	99.280	0.041	98.421	0.061	97.628	65.975	99.355	0.035	-	-
26-Sep-13	-	-	99.294	0.047	98.397	0.054	97.630	66.097	99.344	0.037	-	-
27-Sep-13	-	-	99.300	0.050	98.410	0.057	97.631	66.219	99.345	0.041	-	-
28-Sep-13	-	-	99.299	0.050	98.415	0.059	97.632	66.341	99.344	0.040	-	-
29-Sep-13	-	-	99.309	0.055	98.415	0.059	97.633	66.464	99.352	0.041	-	-
30-Sep-13	-	-	99.299	0.050	98.399	0.054	97.635	66.586	99.343	0.046	-	-
01-Oct-13	-	-	99.434	0.019	98.617	0.127	97.636	66.708	99.376	0.046	-	-
02-Oct-13	-	-	99.495	0.034	98.606	0.122	97.637	66.830	99.386	0.045	-	-
03-Oct-13	-	-	99.437	0.048	98.582	0.113	97.639	66.952	99.386	0.046	-	-
04-Oct-13	-	-	99.478	0.072	98.585	0.113	97.640	67.074	99.398	0.051	-	-
05-Oct-13	-	-	99.475	0.070	98.564	0.105	97.641	67.197	99.392	0.051	-	-
06-Oct-13	-	-	99.533	0.117	98.605	0.120	97.642	67.319	99.397	0.052	-	-
07-Oct-13	-	-	99.533	0.116	98.637	0.133	97.644	67.441	99.400	0.058	-	-
08-Oct-13	-	-	99.524	0.107	98.653	0.139	97.645	67.563	99.404	0.055	-	-
09-Oct-13	-	-	99.559	0.142	98.686	0.153	97.646	67.685	99.421	0.062	-	-
10-Oct-13	-	-	99.560	0.142	98.689	0.154	97.647	67.807	99.411	0.067	-	-
11-Oct-13	-	-	99.550	0.131	98.694	0.155	97.649	67.930	99.431	0.066	-	-
12-Oct-13	-	-	99.537	0.117	98.690	0.153	97.650	68.052	99.437	0.068	-	-
13-Oct-13	-	-	99.514	0.095	98.674	0.146	97.651	68.174	99.419	0.063	-	-
14-Oct-13	-	-	99.494	0.078	98.637	0.131	97.652	68.296	99.404	0.065	-	-
15-Oct-13	-	-	99.482	0.069	98.626	0.126	97.654	68.418	99.397	-	-	-
16-Oct-13	4.1	-	99.483	0.069	98.608	0.119	97.655	68.540	99.400	1.456	-	-
17-Oct-13	2.5	-	-	-	98.588	0.112	97.656	68.663	99.386	1.384	-	-
18-Oct-13	5.1	-	-	-	98.584	0.111	97.657	68.785	-	-	-	-
19-Oct-13	0.7	-	-	-	98.476	0.074	97.659	68.907	-	-	-	-
20-Oct-13	0.5	-	-	-	-	-	97.660	69.029	-	-	-	-
21-Oct-13	2.5	-	-	-	-	-	97.661	69.151	-	-	-	-
22-Oct-13	1.0	-	-	-	-	-	97.663	69.273	-	-	-	-
23-Oct-13	-1.2	-	-	-	-	-	97.664	69.396	-	-	-	-
24-Oct-13	4.9	-	-	-	-	-	97.665	69.518	-	-	-	-
25-Oct-13	2.4	-	-	-	-	-	97.666	69.640	-	-	-	-
26-Oct-13	1.5	-	-	-	-	-	97.668	69.762	-	-	-	-
27-Oct-13	-6.2	-	-	-	-	-	97.669	69.884	-	-	-	-
28-Oct-13	-4.9	-	-	-	-	-	97.670	70.006	-	-	-	-
29-Oct-13	2.3	-	-	-	-	-	97.671	70.129	-	-	-	-
30-Oct-13	5.1	-	-	-	-	-	97.673	70.251	-	-	-	-
31-Oct-13	1.7	-	-	-	-	-	97.674	70.373	-	-	-	-
01-Nov-13	3.6	-	-	-	-	-	97.675	70.495	-	-	-	-
02-Nov-13	-1.9	-	-	-	-	-	97.676	70.617	-	-	-	-
03-Nov-13	-6.3	-	-	-	-	-	97.678	70.739	-	-	-	-
04-Nov-13	-10.8	-	-	-	-	-	97.679	70.862	-	-	-	-
05-Nov-13	-9.0	-	-	-	-	-	97.680	70.984	-	-	-	-
06-Nov-13	-2.2	-	-	-	-	-	97.681	71.106	-	-	-	-
07-Nov-13	-6.2	-	-	-	-	-	97.683	71.228	-	-	-	-
08-Nov-13	-7.3	-	-	-	-	-	97.684	71.350	-	-	-	-
09-Nov-13	-10.7	-	-	-	-	-	97.685	71.472	-	-	-	-
10-Nov-13	-16.4	-	-	-	-	-	97.687	71.595	-	-	-	-
11-Nov-13	-6.1	-	-	-	-	-	97.688	71.717	-	-	-	-
12-Nov-13	-2.3	-	-	-	-	-	97.689	71.839	-	-	-	-
13-Nov-13	-4.6	-	-	-	-	-	97.690	71.961	-	-	-	-
14-Nov-13	-3.0	-	-	-	-	-	97.692	72.083	-	-	-	-
15-Nov-13	-4.7	-	-	-	-	-	97.693	72.205	-	-	-	-
16-Nov-13	-13.4	-	-	-	-	-	97.694	72.328	-	-	-	-
17-Nov-13	-17.0	-	-	-	-	-	97.695	72.450	-	-	-	-
18-Nov-13	-19.5	-	-	-	-	-	97.697	72.572	-	-	-	-
19-Nov-13	-22.0	-	-	-	-	-	97.698	72.694	-	-	-	-
20-Nov-13	-23.2	-	-	-	-	-	97.699	72.816	-	-	-	-
21-Nov-13	-28.6	-	-	-	-	-	97.700	72.938	-	-	-	-
22-Nov-13	-27.1	-	-	-	-	-	97.702	73.061	-	-	-	-
23-Nov-13	-7.9	-	-	-	-	-	97.703	73.183	-	-	-	-
24-Nov-13	-2.4	-	-	-	-	-	97.704	73.305	-	-	-	-
25-Nov-13	-12.7	-	-	-	-	-	97.706	73.427	-	-	-	-
26-Nov-13	-9.3	-	-	-	-	-	97.707	73.549	-	-	-	-
27-Nov-13	-11.1	-	-	-	-	-	97.708	73.671	-	-	-	-
28-Nov-13	-8.4	-	-	-	-	-	97.709	73.794	-	-	-	-
29-Nov-13	-5.2	-	-	-	-	-	97.711	73.916	-	-	-	-
30-Nov-13	-9.9	-	-	-	-	-	97.712	74.038	-	-	-	-
01-Dec-13	-7.5	-	-	-	-	-	97.713	74.160	-	-	-	-
02-Dec-13	-11.6	-	-	-	-	-	97.714	74.282	-	-	-	-
03-Dec-13	-17.6	-	-	-	-	-	97.716	74.404	-	-	-	-
04-Dec-13	-21.8	-	-	-	-	-	97.717	74.527	-	-	-	-
05-Dec-13	-27.0	-	-	-	-	-	97.718	74.649	-	-	-	-
06-Dec-13	-30.0	-	-	-	-	-	97.719	74.771	-	-	-	-
07-Dec-13	-21.5	-	-	-	-	-	97.721	74.893	-	-	-	-
08-Dec-13	-22.8	-	-	-	-	-	97.722	75.015	-	-	-	-
09-Dec-13	-19.4	-	-	-	-	-	97.723	75.137	-	-	-	-
10-Dec-13	-25.1	-	-	-	-	-	97.724	75.260	-	-	-	-
11-Dec-13	-29.0	-	-	-	-	-	97.726	75.382	-	-	-	-
12-Dec-13	-29.3	-	-	-	-	-	97.727	75.504	-	-	-	-
13-Dec-13	-25.9	-	-	-	-	-	97.728	75.626	-	-	-	-
14-Dec-13	-23.0	-	-	-	-	-	97.730	75.748	-	-	-	-
15-Dec-13	-9.3	-	-	-	-	-	97.731	75.870	-	-	-	-
16-Dec-13	-20.5	-	-	-	-	-	97.732	75.993	-	-	-	-
17-Dec-13	-25.3	-	-	-	-	-	97.733	76.115	-	-	-	-
18-Dec-13	-26.7	-	-	-	-	-	97.735	76.237	-	-	-	-
19-Dec-13	-27.9	-	-	-	-	-	97.736	76.359	-	-	-	-
20-Dec-13	-34.7	-	-	-	-	-	97.737	76.481	-	-	-	-
21-Dec-13	-37.2	-	-	-	-	-	97.738	76.603	-	-	-	-
22-Dec-13	-27.7	-	-	-	-	-	97.740	76.726	-	-	-	-
23-Dec-13	-11.7	-	-	-	-	-	97.741	76.848	-	-	-	-
24-Dec-13	-15.8	-	-	-	-	-	97.742	76.970	-	-	-	-
25-Dec-13	-16.4	-	-	-	-	-	97.743	77.092	-	-	-	-
26-Dec-13	-17.0	-	-	-	-	-	97.745	77.214	-	-	-	-
27-Dec-13	-24.7	-	-	-	-	-	97.746	77.336	-	-	-	-
28-Dec-13	-30.7	-	-	-	-	-	97.747	77.459	-	-	-	-
29-Dec-13	-33.6	-	-	-	-	-	97.748	77.581	-	-	-	-
30-Dec-13	-35.6	-	-	-	-	-	97.750	77.703	-	-	-	-
31-Dec-13	-35.4	-	-	-	-	-	97.751	77.825	-	-	-	-
01-Jan-14	-35.6	-	-	-	-	-	97.752	77.947	-	-	-	-
02-Jan-14	-11.8	-	-	-	-	-	97.754	78.069	-	-	-	-
03-Jan-14	-25.3	-	-	-	-	-	97.755	78.192	-	-	-	-
04-Jan-14	-30.6	-	-	-	-	-	97.756	78.314	-	-	-	-
05-Jan-14	-31.5	-	-	-	-	-	97.757	78.436	-	-	-	-
06-Jan-14	-23.4	-	-	-	-	-	97.759	78.558	-	-	-	-
07-Jan-14	-27.4	-	-	-	-	-	97.760	78.680	-	-	-	-
08-Jan-14	-13.5	-	-	-	-	-	97.761	78.802	-	-	-	-
09-Jan-14	-9.2	-	-	-	-	-	97.762	78.925	-	-	-	-
10-Jan-14	-13.9	-	-	-	-	-	97.764	79.047	-	-	-	-
11-Jan-14	-13.4	-	-	-	-	-	97.765	79.169	-	-	-	-
12-Jan-14	-19.5	-	-	-	-	-	97.766	79.291	-	-	-	-
13-Jan-14	-18.7	-	-	-	-	-	97.767	79.413	-	-	-	-
14-Jan-14	-17.7	-	-	-	-	-	97.769	79.535	-	-	-	-
15-Jan-14	-0.6	-	-	-	-	-	97.770	79.658	-	-	-	-
16-Jan-14	-3.6	-	-	-	-	-	97.771	79.780	-	-	-	-
17-Jan-14	-0.9	-	-	-	-	-	97.772	79.902	-	-	-	-
18-Jan-14	-7.6	-	-	-	-	-	97.774	80.024	-	-	-	-
19-Jan-14	-17.1	-	-	-	-	-	97.775	80.146	-	-	-	-
20-Jan-14	-18.7	-	-	-	-	-	97.776	80.268	-	-	-	-
21-Jan-14	-18.8	-	-	-	-	-	97.778	80.391	-	-	-	-
22-Jan-14	-16.7	-	-	-	-	-	97.779	80.513	-	-	-	-
23-Jan-14	-1.9	-	-	-	-	-	97.780	80.635	-	-	-	-
24-Jan-14	-4.7	-	-	-	-	-	97.781	80.757	-	-	-	-
25-Jan-14	-8.2	-	-	-	-	-	97.783	80.879	-	-	-	-
26-Jan-14	-28.1	-	-	-	-	-	97.784	81.001	-	-	-	-
27-Jan-14	-26.2	-	-	-	-	-	97.785	81.124	-	-	-	-
28-Jan-14	-14.5	-	-	-	-	-	97.786	81.246	-	-	-	-
29-Jan-14	-23.3	-	-	-	-	-	97.788	81.368	-	-	-	-
30-Jan-14	-20.6	-	-	-	-	-	97.789	81.490	-	-	-	-
31-Jan-14	-16.9	-	-	-	-	-	97.790	81.612	-	-	-	-
01-Feb-14	-14.6	-	-	-	-	-	97.791	81.734	-	-	-	-
02-Feb-14	-16.5	-	-	-	-	-	97.793	81.857	-	-	-	-
03-Feb-14	-19.6	-	-	-	-	-	97.794	81.979	-	-	-	-
04-Feb-14	-22.2	-	-	-	-	-	97.795	82.101	-	-	-	-
05-Feb-14	-22.9	-	-	-	-	-	97.797	82.223	-	-	-	-
06-Feb-14	-16.1	-	-	-	-	-	97.798	82.345	-	-	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
07-Feb-14	-20.1	-	-	-	-	-	97.799	82.467	-	-	-	-
08-Feb-14	-27.4	-	-	-	-	-	97.800	82.590	-	-	-	-
09-Feb-14	-26.0	-	-	-	-	-	97.802	82.712	-	-	-	-
10-Feb-14	-24.9	-	-	-	-	-	97.803	82.834	-	-	-	-
11-Feb-14	-27.7	-	-	-	-	-	97.804	82.956	-	-	-	-
12-Feb-14	-26.6	-	-	-	-	-	97.805	83.078	-	-	-	-
13-Feb-14	-19.6	-	-	-	-	-	97.807	83.200	-	-	-	-
14-Feb-14	-19.8	-	-	-	-	-	97.808	83.323	-	-	-	-
15-Feb-14	-10.2	-	-	-	-	-	97.809	83.445	-	-	-	-
16-Feb-14	-12.2	-	-	-	-	-	97.810	83.567	-	-	-	-
17-Feb-14	-8.8	-	-	-	-	-	97.812	83.689	-	-	-	-
18-Feb-14	-9.9	-	-	-	-	-	97.813	83.811	-	-	-	-
19-Feb-14	-8.2	-	-	-	-	-	97.814	83.933	-	-	-	-
20-Feb-14	-13.1	-	-	-	-	-	97.815	84.056	-	-	-	-
21-Feb-14	-19.4	-	-	-	-	-	97.817	84.178	-	-	-	-
22-Feb-14	-24.5	-	-	-	-	-	97.818	84.300	-	-	-	-
23-Feb-14	-23.8	-	-	-	-	-	97.819	84.422	-	-	-	-
24-Feb-14	-22.1	-	-	-	-	-	97.821	84.544	-	-	-	-
25-Feb-14	-18.5	-	-	-	-	-	97.822	84.666	-	-	-	-
26-Feb-14	-19.3	-	-	-	-	-	97.823	84.789	-	-	-	-
27-Feb-14	-20.5	-	-	-	-	-	97.824	84.911	-	-	-	-
28-Feb-14	-29.0	-	-	-	-	-	97.826	85.033	-	-	-	-
01-Mar-14	-28.6	-	-	-	-	-	97.827	85.155	-	-	-	-
02-Mar-14	-25.3	-	-	-	-	-	97.828	85.277	-	-	-	-
03-Mar-14	-24.4	-	-	-	-	-	97.829	85.399	-	-	-	-
04-Mar-14	-21.8	-	-	-	-	-	97.831	85.522	-	-	-	-
05-Mar-14	-15.6	-	-	-	-	-	97.832	85.644	-	-	-	-
06-Mar-14	-19.1	-	-	-	-	-	97.833	85.766	-	-	-	-
07-Mar-14	-15.6	-	-	-	-	-	97.834	85.888	-	-	-	-
08-Mar-14	-11.9	-	-	-	-	-	97.836	86.010	-	-	-	-
09-Mar-14	-8.2	-	-	-	-	-	97.837	86.132	-	-	-	-
10-Mar-14	-10.4	-	-	-	-	-	97.838	86.255	-	-	-	-
11-Mar-14	-3.3	-	-	-	-	-	97.839	86.377	-	-	-	-
12-Mar-14	6.4	-	-	-	-	-	97.841	86.499	-	-	-	-
13-Mar-14	-0.8	-	-	-	-	-	97.842	86.621	-	-	-	-
14-Mar-14	-3.6	-	-	-	-	-	97.843	86.743	-	-	-	-
15-Mar-14	-0.1	-	-	-	-	-	97.845	86.865	-	-	-	-
16-Mar-14	4.8	-	-	-	-	-	97.846	86.988	-	-	-	-
17-Mar-14	-1.2	-	-	-	-	-	97.847	87.110	-	-	-	-
18-Mar-14	-0.8	-	-	-	-	-	97.848	87.232	-	-	-	-
19-Mar-14	-3.3	-	-	-	-	-	97.850	87.354	-	-	-	-
20-Mar-14	-17.2	-	-	-	-	-	97.851	87.476	-	-	-	-
21-Mar-14	-19.7	-	-	-	-	-	97.852	87.598	-	-	-	-
22-Mar-14	-17.1	-	-	-	-	-	97.853	87.721	-	-	-	-
23-Mar-14	-11.7	-	-	-	-	-	97.855	87.843	-	-	-	-
24-Mar-14	-12.4	-	-	-	-	-	97.856	87.965	-	-	-	-
25-Mar-14	-9.2	-	-	-	-	-	97.857	88.087	-	-	-	-
26-Mar-14	-15.8	-	-	-	-	-	97.858	88.209	-	-	-	-
27-Mar-14	-14.6	-	-	-	-	-	97.860	88.331	-	-	-	-
28-Mar-14	-8.1	-	-	-	-	-	97.861	88.454	-	-	-	-
29-Mar-14	-13.6	-	-	-	-	-	97.862	88.576	-	-	-	-
30-Mar-14	-21.5	-	-	-	-	-	97.863	88.698	-	-	-	-
31-Mar-14	-9.0	-	-	-	-	-	97.865	88.820	-	-	-	-
01-Apr-14	-8.8	-	-	-	-	-	97.866	88.942	-	-	-	-
02-Apr-14	-13.4	-	-	-	-	-	97.867	89.065	-	-	-	-
03-Apr-14	-10.8	-	-	-	-	-	97.869	89.187	-	-	-	-
04-Apr-14	-1.5	-	-	-	-	-	97.870	89.309	-	-	-	-
05-Apr-14	-5.8	-	-	-	-	-	97.871	89.431	-	-	-	-
06-Apr-14	-2.4	-	-	-	-	-	97.872	89.553	-	-	-	-
07-Apr-14	4.6	-	-	-	-	-	97.874	89.675	-	-	-	-
08-Apr-14	11.1	-	-	-	-	-	97.875	89.798	-	-	-	-
09-Apr-14	3.2	-	-	-	-	-	97.876	89.920	-	-	-	-
10-Apr-14	-3.3	-	-	-	-	-	97.877	90.042	-	-	-	-
11-Apr-14	-6.5	-	-	-	-	-	97.879	90.164	-	-	-	-
12-Apr-14	-7.6	-	-	-	-	-	97.880	90.286	-	-	-	-
13-Apr-14	-8.2	-	-	-	-	-	97.881	90.408	-	-	-	-
14-Apr-14	1.3	-	-	-	-	-	97.882	90.531	-	-	-	-
15-Apr-14	-0.9	-	-	-	-	-	97.884	90.653	-	-	-	-
16-Apr-14	-3.7	-	-	-	-	-	97.885	90.775	-	-	-	-
17-Apr-14	0.7	-	-	-	-	-	97.886	90.897	-	-	-	-
18-Apr-14	-1.5	-	-	-	-	-	97.888	91.019	-	-	-	-
19-Apr-14	3.0	-	-	-	-	-	97.889	91.141	-	-	-	-
20-Apr-14	4.8	-	-	-	-	-	97.890	91.264	-	-	-	-
21-Apr-14	7.4	-	-	-	-	-	97.891	91.386	-	-	-	-
22-Apr-14	5.8	-	-	-	-	-	97.893	91.508	-	-	-	-
23-Apr-14	6.5	-	-	-	-	-	97.894	91.630	-	-	-	-
24-Apr-14	5.1	-	-	-	-	-	97.895	91.752	-	-	-	-
25-Apr-14	5.3	-	-	-	-	-	97.896	91.874	-	-	-	-
26-Apr-14	4.7	-	-	-	-	-	97.898	91.997	-	-	-	-
27-Apr-14	4.1	-	-	-	-	-	97.899	92.119	-	-	-	-
28-Apr-14	7.5	-	-	-	-	-	97.900	92.241	-	-	-	-
29-Apr-14	10.0	-	-	-	-	-	97.901	92.363	-	-	-	-
30-Apr-14	13.4	-	-	-	-	-	97.903	92.485	-	-	-	-
01-May-14	10.6	3.6	-	-	-	-	97.904	92.607	-	-	-	-
02-May-14	-2.1	0	-	-	-	-	97.905	92.730	-	-	-	-
03-May-14	-1.4	0	-	-	-	-	97.906	92.852	-	-	-	-
04-May-14	0.9	0.2	-	-	-	-	97.908	92.974	-	-	-	-
05-May-14	3.3	1.8	-	-	-	-	97.909	93.096	-	-	-	-
06-May-14	2.1	0	-	-	-	-	97.910	93.218	-	-	-	-
07-May-14	0.3	0	-	-	-	-	97.925	95.132	-	-	-	-
08-May-14	0.8	4	-	-	-	-	97.853	85.804	-	-	-	-
09-May-14	1.4	0	-	-	-	-	97.800	79.138	99.602	1.984	-	-
10-May-14	0.1	3.2	-	-	-	-	97.768	75.219	99.582	1.865	-	-
11-May-14	6.5	0.8	98.388	0.114	-	-	97.747	72.800	99.571	1.802	-	-
12-May-14	6.1	0	98.484	0.201	-	-	97.756	73.810	99.561	1.746	-	-
13-May-14	7.9	0	98.530	0.218	-	-	97.765	74.946	99.571	1.804	-	-
14-May-14	13.0	0	98.471	0.196	-	-	97.752	73.354	99.579	1.851	-	-
15-May-14	6.0	16.2	98.451	0.187	-	-	97.735	71.429	99.588	1.905	-	-
16-May-14	6.8	0.2	98.692	0.290	-	-	97.821	81.725	99.648	2.285	-	-
17-May-14	11.0	0	98.640	0.265	-	-	97.868	87.610	99.689	2.564	-	-
18-May-14	12.9	0	98.566	0.232	-	-	97.869	87.812	99.710	2.720	-	-
19-May-14	16.4	0	98.520	0.213	-	-	97.837	83.688	99.714	2.751	-	-
20-May-14	13.6	5.4	98.499	0.206	-	-	97.817	81.264	99.709	2.715	-	-
21-May-14	15.5	1.2	98.509	0.209	-	-	97.799	78.996	99.708	2.708	-	-
22-May-14	14.9	0	98.532	0.218	-	-	97.762	74.604	99.703	2.672	-	-
23-May-14	22.1	0	98.508	0.209	-	-	97.730	70.797	99.697	2.629	-	-
24-May-14	12.6	1.4	98.479	0.198	-	-	97.703	67.652	99.691	2.587	-	-
25-May-14	12.5	0	98.478	0.197	-	-	97.683	65.466	99.683	2.531	-	-
26-May-14	11.1	7.6	98.507	0.208	-	-	97.657	62.548	99.678	2.496	-	-
27-May-14	8.2	5.8	98.452	0.183	-	-	97.638	60.551	99.701	2.664	-	-
28-May-14	7.9	0	98.551	0.225	-	-	97.668	63.770	99.710	2.732	-	-
29-May-14	7.2	29	98.525	0.214	-	-	97.673	64.385	99.713	2.755	-	-
30-May-14	9.0	8.2	99.116	0.611	-	-	97.743	72.310	99.757	3.099	-	-
31-May-14	12.9	0	99.087	0.580	-	-	97.955	99.285	99.807	3.519	-	-
01-Jun-14	13.4	7	98.942	0.449	-	-	98.110	121.514	99.909	4.479	-	-
02-Jun-14	17.1	0	98.798	0.348	-	-	98.141	126.167	99.925	4.634	-	-
03-Jun-14	14.4	8.4	98.693	0.288	-	-	98.105	120.782	99.915	4.533	-	-
04-Jun-14	6.9	2.8	98.655	0.269	-	-	98.078	116.690	99.893	4.314	-	-
05-Jun-14	7.3	0.6	98.651	0.267	-	-	98.090	118.557	99.877	4.159	-	-
06-Jun-14	9.0	0.2	98.599	0.244	-	-	98.081	117.155	99.861	4.007	-	-
07-Jun-14	11.2	0	98.537	0.218	-	-	98.028	109.510	99.844	3.850	-	-
08-Jun-14	12.8	0	98.476	0.195	-	-	97.962	100.183	99.831	3.734	-	-
09-Jun-14	11.8	3	98.422	0.140	-	-	97.897	91.390	99.814	3.584	-	-
10-Jun-14	14.0	0.2	98.425	0.142	-	-	97.882	89.504	99.797	3.438	-	-
11-Jun-14	14.2	1.2	98.393	0.110	-	-	97.852	85.596	99.781	3.304	-	-
12-Jun-14	16.8	0	98.358	0.083	-	-	97.772	75.793	99.766	3.181	-	-
13-Jun-14	17.0	0	98.333	0.068	-	-	97.711	68.607	99.742	2.990	-	-
14-Jun-14	21.2	0	98.272	0.041	-	-	97.664	63.405	99.725	2.859	-	-
15-Jun-14	21.3	0	98.229	0.029	-	-	97.619	58.507	99.704	2.701	-	-
16-Jun-14	17.6	0	98.203	0.024	-	-	97.566	52.990	99.674	2.485	-	-
17-Jun-14	16.9	0	98.172	0.018	-	-	97.521	48.603	99.630	2.187	-	-
18-Jun-14	20.1	0	98.154	0.016	-	-	97.506	47.123	99.590	1.932	-	-
19-Jun-14	18.8	0	98.148	0.015	-	-	97.448	41.804	99.545	1.674	-	-
20-Jun-14	17.9	1.6	98.136	0.014	-	-	97.410	38.416	99.508	1.473	-	-
21-Jun-14	15.3	10.8	98.144	0.015	-	-	97.390	36.756	99.471	1.287	-	-
22-Jun-14	18.7	0	98.310	0.055	-	-	97.385	36.299	99.493	1.397	-	-
23-Jun-14	17.3	14.8	98.251	0.034	-	-	97.390	36.684	99.494	1.403	-	-
24-Jun-14	22.0	0	98.466	0.191	-	-	97.404	37.924	99.495	1.409	-	-
25-Jun-14	22.2	0	98.353	0.078	-	-	97.389	36.611	99.502	1.446	-	-
26-Jun-14	18.3	19.4	98.292	0.047	-	-	97.369	34.989	99.514	1.510	-	-
27-Jun-14	17.9	0.2	98.308	0.054	-	-	97.374	35.367	99.548	1.698	-	-
28-Jun-14	19.3	0.4	98.272	0.040	-	-	97.369	35.001	99.647	2.305	-	-
29-Jun-14	20.0	0	98.230	0.028	-	-	97.342	32.772	99.646	2.299	-	-
30-Jun-14	20.1	0	98.188	0.020	-	-	97.313	30.459	99.627	2.175	-	-
01-Jul-14	19.0	0	98.163	0.017	-	-	97.293	28.977	99.599	2.000	-	-
02-Jul-14	21.4	0	98.145	0.014	-	-	97.262	26.655	99.579	1.880	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
03-Jul-14	22.1	0.4	98.130	0.013	-	-	97.231	24.497	99.544	1.681	-	-
04-Jul-14	21.5	16.2	98.116	0.011	-	-	97.211	23.097	99.503	1.453	-	-
05-Jul-14	20.5	0	98.232	0.029	-	-	97.204	22.665	99.470	1.288	-	-
06-Jul-14	16.5	8.6	98.150	0.015	-	-	97.182	21.188	99.494	1.408	-	-
07-Jul-14	16.3	0.4	98.191	0.021	-	-	97.164	20.011	99.587	1.927	-	-
08-Jul-14	19.0	1.6	98.155	0.015	-	-	97.145	18.866	99.545	1.685	-	-
09-Jul-14	23.0	0.4	98.146	0.014	-	-	97.125	17.635	99.498	1.431	-	-
10-Jul-14	16.3	9.6	98.173	0.018	-	-	97.100	16.215	99.441	1.156	-	-
11-Jul-14	16.7	0	98.204	0.022	-	-	97.099	16.134	99.451	1.202	-	-
12-Jul-14	14.5	0	98.216	0.025	-	-	97.097	16.053	99.443	1.166	-	-
13-Jul-14	17.7	0	98.163	0.016	-	-	97.086	15.412	99.411	1.030	-	-
14-Jul-14	24.5	0	98.148	0.014	-	-	97.064	14.190	99.371	0.874	-	-
15-Jul-14	25.8	0	98.133	0.013	-	-	97.042	13.069	99.324	0.709	-	-
16-Jul-14	20.4	1.6	98.115	0.011	-	-	97.019	11.894	99.283	0.581	-	-
17-Jul-14	17.9	0	98.108	0.010	-	-	97.021	12.020	99.239	0.460	-	-
18-Jul-14	18.7	0	98.092	0.009	-	-	97.032	12.546	99.192	0.347	-	-
19-Jul-14	15.2	8.2	98.076	0.008	-	-	97.012	11.588	99.158	0.277	-	-
20-Jul-14	15.1	0	98.096	0.009	-	-	97.026	12.253	99.230	0.436	-	-
21-Jul-14	15.8	0	98.083	0.008	-	-	97.047	13.296	99.240	0.462	-	-
22-Jul-14	19.7	0	98.088	0.009	-	-	97.046	13.274	99.220	0.412	-	-
23-Jul-14	21.8	0	98.063	0.007	-	-	97.038	12.842	99.183	0.327	-	-
24-Jul-14	22.4	3.4	98.052	0.006	-	-	97.024	12.168	99.157	0.275	-	-
25-Jul-14	21.3	0	98.067	0.007	-	-	97.017	11.802	99.165	0.291	-	-
26-Jul-14	21.3	0	98.050	0.006	-	-	97.014	11.684	99.181	0.324	-	-
27-Jul-14	18.8	11.4	98.035	0.006	-	-	97.002	11.088	99.167	0.295	-	-
28-Jul-14	22.7	0	98.084	0.008	-	-	97.002	11.067	99.152	0.267	-	-
29-Jul-14	24.6	0	98.239	0.029	-	-	97.021	12.012	99.121	0.213	-	-
30-Jul-14	24.8	11.8	98.211	0.023	-	-	97.021	11.991	99.101	0.183	-	-
31-Jul-14	18.5	0.8	98.242	0.029	-	-	97.007	11.339	99.139	0.244	-	-
01-Aug-14	15.9	0	98.231	0.027	-	-	97.018	11.850	99.099	0.180	-	-
02-Aug-14	19.5	1.6	98.178	0.017	-	-	96.999	10.965	99.105	0.190	-	-
03-Aug-14	22.9	0	98.175	0.017	-	-	97.006	11.277	99.099	0.181	-	-
04-Aug-14	21.2	0	98.174	0.017	-	-	96.988	10.414	99.104	0.189	-	-
05-Aug-14	21.3	0	98.144	0.013	-	-	96.971	9.672	99.099	0.180	-	-
06-Aug-14	22.4	2.4	98.116	0.010	-	-	96.952	8.829	99.101	0.183	-	-
07-Aug-14	19.1	0	98.143	0.013	-	-	96.944	8.516	99.100	0.182	-	-
08-Aug-14	15.2	0.8	98.105	0.010	-	-	96.926	7.764	99.083	0.192	-	-
09-Aug-14	14.8	4.8	98.077	0.008	-	-	96.925	7.747	99.105	0.227	-	-
10-Aug-14	18.1	0	98.106	0.010	-	-	96.922	7.611	99.136	0.216	-	-
11-Aug-14	20.6	0	98.064	0.007	-	-	96.911	7.166	99.129	0.185	-	-
12-Aug-14	20.3	0	98.046	0.006	-	-	96.914	7.304	99.131	0.150	-	-
13-Aug-14	25.5	0	98.045	0.006	-	-	96.907	7.031	99.152	0.119	-	-
14-Aug-14	21.4	0	98.038	0.005	-	-	96.892	6.473	99.193	0.101	-	-
15-Aug-14	23.2	0	98.030	0.005	-	-	96.886	6.256	99.187	0.077	-	-
16-Aug-14	21.6	0	98.018	0.005	98.453	0.090	96.888	6.329	99.175	0.061	-	-
17-Aug-14	21.5	0	98.017	0.005	98.541	0.117	96.887	6.297	99.162	0.046	-	-
18-Aug-14	16.1	0.4	98.007	0.004	98.587	0.134	96.880	6.048	99.155	0.037	-	-
19-Aug-14	16.2	0.2	98.011	0.004	98.588	0.133	96.877	5.943	99.180	0.049	-	-
20-Aug-14	10.4	0	98.014	0.005	98.600	0.137	96.876	5.909	99.185	0.035	-	-
21-Aug-14	8.5	0	98.015	0.005	98.596	0.135	96.883	6.157	99.175	0.030	-	-
22-Aug-14	9.9	0	98.012	0.005	98.602	0.136	96.880	6.052	99.176	0.030	-	-
23-Aug-14	10.4	0	98.009	0.004	98.624	0.145	96.879	6.018	99.179	0.032	-	-
24-Aug-14	12.0	0	97.999	0.004	98.625	0.144	96.882	6.125	99.205	0.034	-	-
25-Aug-14	17.1	0	97.999	0.004	98.627	0.144	96.882	6.126	99.212	0.030	-	-
26-Aug-14	18.7	8	97.992	0.004	98.623	0.141	96.875	5.880	99.216	0.030	-	-
27-Aug-14	16.9	0.6	98.018	0.005	98.657	0.155	96.894	6.562	99.247	0.028	-	-
28-Aug-14	9.7	0.8	98.002	0.004	98.634	0.144	96.886	6.272	99.256	0.026	-	-
29-Aug-14	13.5	0	98.001	0.004	98.606	0.131	96.880	6.059	99.278	0.024	-	-
30-Aug-14	12.9	10.4	97.991	0.004	98.616	0.134	96.880	6.060	99.309	0.037	-	-
31-Aug-14	12.9	0.8	98.020	0.005	98.598	0.126	96.912	7.244	99.385	0.099	-	-
01-Sep-14	12.7	0.8	98.019	0.005	98.527	0.101	96.914	7.323	99.409	0.082	-	-
02-Sep-14	9.2	0.4	98.016	0.005	98.469	0.084	96.920	7.558	99.456	0.076	-	-
03-Sep-14	11.0	0.6	98.004	0.004	98.434	0.075	96.921	7.599	99.477	0.072	-	-
04-Sep-14	12.6	0.4	98.002	0.004	98.419	0.071	96.930	7.959	99.489	0.070	-	-
05-Sep-14	7.8	0	97.998	0.004	98.375	0.062	96.923	7.680	99.492	0.065	-	-
06-Sep-14	6.3	3.8	97.996	0.004	98.339	0.055	96.917	7.445	99.494	0.063	-	-
07-Sep-14	4.7	0.8	98.008	0.005	98.365	0.059	96.925	7.762	99.501	0.069	-	-
08-Sep-14	2.8	0	98.001	0.004	98.483	0.084	96.925	7.763	99.510	0.076	-	-
09-Sep-14	2.8	0	98.000	0.004	98.549	0.102	96.928	7.884	99.508	0.075	-	-
10-Sep-14	3.8	0	98.001	0.005	98.570	0.108	96.934	8.128	99.511	0.078	-	-
11-Sep-14	8.0	0	98.000	0.005	98.573	0.108	96.929	7.927	99.516	0.082	-	-
12-Sep-14	7.9	0	97.999	0.005	98.569	0.106	96.930	7.968	99.518	0.084	-	-
13-Sep-14	5.1	0	97.998	0.004	98.535	0.095	96.924	7.729	99.518	0.084	-	-
14-Sep-14	8.7	0.2	98.001	0.005	98.463	0.076	96.921	7.611	99.518	0.084	-	-
15-Sep-14	9.9	0	98.001	0.005	98.400	0.062	96.920	7.573	99.518	0.084	-	-
16-Sep-14	9.4	0	98.005	0.005	98.349	0.053	96.913	7.301	99.515	0.081	-	-
17-Sep-14	9.7	0	97.999	0.005	98.312	0.047	96.916	7.418	99.516	0.082	-	-
18-Sep-14	12.6	0	97.997	0.005	98.294	0.044	96.912	7.264	99.516	0.082	-	-
19-Sep-14	14.7	2.8	98.000	0.005	98.286	0.043	96.913	7.304	99.530	0.089	-	-
20-Sep-14	13.9	1.4	98.008	0.005	98.334	0.049	96.919	7.539	99.539	0.093	-	-
21-Sep-14	17.9	0	98.009	0.005	98.334	0.049	96.924	7.738	99.536	0.083	-	-
22-Sep-14	22.0	0	98.009	0.005	98.303	0.044	96.931	8.020	99.542	0.084	-	-
23-Sep-14	15.9	1.2	98.015	0.005	98.297	0.043	96.933	8.103	99.541	0.077	-	-
24-Sep-14	12.8	0.6	98.024	0.006	98.304	0.043	96.938	8.309	99.554	0.089	-	-
25-Sep-14	10.7	1	98.028	0.006	98.289	0.041	96.939	8.351	99.556	0.090	-	-
26-Sep-14	4.8	23.6	98.033	0.006	98.297	0.042	96.938	8.311	99.555	0.090	-	-
27-Sep-14	5.1	0.4	98.066	0.008	98.431	0.063	96.995	10.821	99.574	0.111	-	-
28-Sep-14	8.1	0	98.288	0.050	98.415	0.059	97.041	13.079	99.569	0.104	-	-
29-Sep-14	12.8	0	98.178	0.021	98.384	0.053	97.093	15.880	99.560	0.095	-	-
30-Sep-14	9.7	0.8	98.137	0.015	98.347	0.047	97.098	16.165	99.552	0.087	-	-
01-Oct-14	3.8	1.6	98.122	0.013	98.333	0.045	97.105	16.566	99.546	0.082	-	-
02-Oct-14	-0.2	1.4	98.110	0.012	98.348	0.047	97.122	17.560	99.556	0.081	-	-
03-Oct-14	1.1	1.4	98.098	0.011	98.330	0.044	97.121	17.502	99.550	0.075	-	-
04-Oct-14	4.0	0.4	98.097	0.011	98.335	0.044	97.114	17.093	99.552	0.076	-	-
05-Oct-14	5.5	0	98.102	0.012	98.344	0.045	97.110	16.862	99.547	0.072	-	-
06-Oct-14	4.3	0	98.101	0.012	98.334	0.044	97.119	17.389	99.547	0.071	-	-
07-Oct-14	3.2	0	98.110	0.012	98.328	0.043	97.114	17.098	99.541	0.066	-	-
08-Oct-14	0.6	0	98.100	0.011	98.316	0.041	97.105	16.578	99.538	0.062	-	-
09-Oct-14	5.1	0	98.100	0.012	98.309	0.040	97.098	16.179	99.533	0.058	-	-
10-Oct-14	13.5	0	98.099	0.011	98.304	0.039	97.093	15.898	99.533	0.058	-	-
11-Oct-14	13.6	0.2	98.097	0.011	98.307	0.039	97.081	15.230	99.531	0.056	-	-
12-Oct-14	10.3	0	98.097	0.011	98.301	0.038	97.076	14.956	99.528	0.053	-	-
13-Oct-14	6.5	0	98.099	0.012	98.298	0.037	97.074	14.849	99.525	0.051	-	-
14-Oct-14	8.3	0	98.090	0.011	98.295	0.037	97.068	14.525	99.525	0.050	-	-
15-Oct-14	3.4	0	98.091	0.011	98.293	0.036	97.067	14.472	99.520	0.047	-	-
16-Oct-14	1.7	0	98.093	0.011	98.298	0.036	97.060	14.099	99.517	0.045	-	-
17-Oct-14	7.3	0	98.099	0.012	98.303	0.037	97.049	13.521	99.512	0.041	-	-
18-Oct-14	9.3	0	98.083	0.011	98.292	0.035	97.043	13.212	99.521	0.047	-	-
19-Oct-14	9.5	0	98.092	0.011	98.289	0.035	97.043	13.213	99.523	0.047	-	-
20-Oct-14	10.6	0	98.098	0.012	98.301	0.036	97.037	12.907	99.517	0.043	-	-
21-Oct-14	8.1	0	98.097	0.012	98.338	0.040	97.035	12.807	99.522	0.046	-	-
22-Oct-14	7.9	0	98.095	0.012	98.328	0.038	97.034	12.749	99.522	0.046	-	-
23-Oct-14	7.2	16	98.094	0.012	98.318	0.037	97.030	12.531	99.524	0.048	-	-
24-Oct-14	0.8	6.6	98.144	0.018	98.432	0.051	-	-	99.550	0.071	-	-
25-Oct-14	-	-	98.385	0.122	98.470	0.057	-	-	99.566	0.089	-	-
26-Oct-14	-	-	98.311	0.067	98.443	0.051	-	-	99.570	0.097	-	-
27-Oct-14	-	-	98.289	0.056	98.418	0.047	-	-	99.570	0.101	-	-
28-Oct-14	-	-	98.274	0.049	98.401	0.043	-	-	99.572	0.108	-	-
29-Oct-14	-	-	98.269	0.047	98.386	0.041	-	-	99.568	0.108	-	-
30-Oct-14	-	-	98.251	0.040	98.374	0.038	-	-	99.560	0.103	-	-
31-Oct-14	-	-	98.245	0.038	98.362	0.036	-	-	99.557	0.104	-	-
01-Nov-14	-	-	98.248	0.039	98.356	0.035	-	-	99.562	0.114	-	-
02-Nov-14	-	-	98.258	0.042	98.358	0.035	-	-	99.558	0.114	-	-
03-Nov-14	-	-	98.269	0.046	98.349	0.033	-	-	99.555	0.115	-	-
04-Nov-14	-	-	98.248	0.038	98.342	0.032	-	-	99.550	0.113	-	-
05-Nov-14	-	-	98.243	0.037	98.338	0.031	-	-	99.552	0.120	-	-
06-Nov-14	-	-	98.238	0.035	98.336	0.030	-	-	99.552	0.125	-	-
07-Nov-14	-	-	98.241	0.036	98.341	0.030	-	-	99.554	0.132	-	-
08-Nov-14	-	-	98.211	0.028	98.308	0.026	-	-	99.535	0.114	-	-
09-Nov-14	-	-	98.174	0.020	98.283	0.024	-	-	99.525	0.107	-	-
10-Nov-14	-	-	98.147	0.016	98.260	0.022	-	-	99.516	0.102	-	-
11-Nov-14	-	-	98.121	0.013	98.248	0.021	-	-	99.506	0.095	-	-
12-Nov-14	-	-	98.114	0.012	98.247	0.020	-	-	99.499	0.092	-	-
13-Nov-14	-	-	98.095	0.011	98.229	0.019	-	-	99.483	0.080	-	-
14-Nov-14	-	-	98.092	0.010	98.238	0.019	-	-	99.329	0.006	-	-
15-Nov-14	-	-	98.082	0.009	98.231	0.018	-	-	99.328	0.007	-	-
16-Nov-14	-	-	98.077	0.009	98.229	0.018	-	-	99.314	0.004	-	-
17-Nov-14	-	-	98.082	0.009	98.237	0.018	-	-	99.300	0.001	-	-
18-Nov-14	-	-	98.080	0.009	98.224	0.017	-	-	99.296	0.000	-	-
19-Nov-14	-	-	98.075	0.009	98.226	0.017	-	-	99.289	0.000	-	-
20-Nov-14	-	-	98.084	0.009	98.236	0.017	-	-	99.286	0.000	-	-
21-Nov-14	-	-	98.092	0.010	98.235	0.016	-	-	99.281	0.000	-	-
22-Nov-14	-	-	98.092	0.010	98.234	0.016	-	-	99.296	0.005	-	-
23-Nov-14	-	-	98.085	0.009	98.229	0.016	-	-	99.276	0.000	-	-
24-Nov-14	-	-	98.080	0.009	98.226	0.015	-	-	99.262	0.000	-	-
25-Nov-14	-	-	98.077	0.009	98.225	0.015	-	-	99.229	0.000	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
26-Nov-14	-	-	98.128	0.013	98.218	0.014	-	-	99.145	0.000	-	-
27-Nov-14	-	-	98.071	0.008	98.209	0.014	-	-	99.217	0.000	-	-
28-Nov-14	-	-	98.049	0.007	98.210	0.013	-	-	99.046	0.000	-	-
29-Nov-14	-	-	98.045	0.006	98.221	0.014	-	-	99.060	0.000	-	-
30-Nov-14	-	-	98.039	0.006	98.208	0.013	-	-	99.030	0.000	-	-
01-Dec-14	-	-	98.028	0.006	98.201	0.012	-	-	99.005	0.000	-	-
02-Dec-14	-	-	98.032	0.006	98.197	0.012	-	-	99.101	0.000	-	-
03-Dec-14	-	-	98.027	0.005	98.206	0.012	-	-	99.105	0.000	-	-
04-Dec-14	-	-	98.014	0.005	98.201	0.012	-	-	99.085	0.000	-	-
05-Dec-14	-	-	98.014	0.005	98.204	0.011	-	-	99.069	0.000	-	-
06-Dec-14	-	-	98.014	0.005	98.202	0.011	-	-	99.072	0.000	-	-
07-Dec-14	-	-	98.014	0.005	98.213	0.011	-	-	99.067	0.000	-	-
08-Dec-14	-	-	98.022	0.005	98.214	0.011	-	-	99.061	0.000	-	-
09-Dec-14	-	-	98.027	0.005	98.212	0.011	-	-	99.062	0.000	-	-
10-Dec-14	-	-	98.027	0.005	98.217	0.011	-	-	99.061	0.000	-	-
11-Dec-14	-	-	98.032	0.005	98.225	0.011	-	-	99.057	0.000	-	-
12-Dec-14	-	-	98.032	0.005	98.227	0.011	-	-	99.052	0.000	-	-
13-Dec-14	-	-	98.031	0.005	98.222	0.010	-	-	99.053	0.000	-	-
14-Dec-14	-	-	98.031	0.005	98.213	0.010	-	-	99.046	0.000	-	-
15-Dec-14	-	-	98.031	0.005	98.211	0.010	-	-	99.058	0.000	-	-
16-Dec-14	-	-	98.026	0.005	98.212	0.009	-	-	99.047	0.000	-	-
17-Dec-14	-	-	98.030	0.005	98.225	0.010	-	-	99.043	0.000	-	-
18-Dec-14	-	-	98.030	0.005	98.219	0.009	-	-	99.045	0.000	-	-
19-Dec-14	-	-	98.026	0.005	98.214	0.009	-	-	99.040	0.000	-	-
20-Dec-14	-	-	98.023	0.005	98.206	0.009	-	-	99.041	0.000	-	-
21-Dec-14	-	-	98.024	0.005	98.212	0.009	-	-	99.039	0.000	-	-
22-Dec-14	-	-	98.021	0.005	98.216	0.008	-	-	99.037	0.000	-	-
23-Dec-14	-	-	98.026	0.005	98.215	0.008	-	-	99.044	0.000	-	-
24-Dec-14	-	-	98.025	0.005	98.215	0.008	-	-	99.043	0.000	-	-
25-Dec-14	-	-	98.014	0.004	98.210	0.008	-	-	99.062	0.000	-	-
26-Dec-14	-	-	-	-	98.210	0.008	-	-	99.049	0.000	-	-
27-Dec-14	-	-	-	-	98.223	0.008	-	-	99.036	0.000	-	-
28-Dec-14	-	-	-	-	98.223	0.008	-	-	99.022	0.000	-	-
29-Dec-14	-	-	-	-	98.250	0.008	-	-	99.009	0.000	-	-
30-Dec-14	-	-	-	-	98.230	-	-	-	99.037	0.000	-	-
31-Dec-14	-	-	-	-	98.214	-	-	-	99.034	0.000	-	-
01-Jan-15	-	-	-	-	98.210	-	-	-	99.022	0.000	-	-
02-Jan-15	-	-	-	-	98.232	-	-	-	98.993	0.000	-	-
03-Jan-15	-	-	-	-	98.199	-	-	-	99.001	0.000	-	-
04-Jan-15	-	-	-	-	98.264	-	-	-	99.009	0.000	-	-
05-Jan-15	-	-	-	-	98.240	-	-	-	99.010	0.000	-	-
06-Jan-15	-	-	-	-	98.222	-	-	-	98.979	0.000	-	-
07-Jan-15	-	-	-	-	98.225	-	-	-	98.983	0.000	-	-
08-Jan-15	-	-	-	-	98.199	-	-	-	99.003	0.000	-	-
09-Jan-15	-	-	-	-	98.188	-	-	-	99.016	0.000	-	-
10-Jan-15	-	-	-	-	98.207	-	-	-	98.981	0.000	-	-
11-Jan-15	-	-	-	-	98.207	-	-	-	98.938	0.000	-	-
12-Jan-15	-	-	-	-	98.207	-	-	-	99.000	0.000	-	-
13-Jan-15	-	-	-	-	98.188	-	-	-	98.996	0.000	-	-
14-Jan-15	-	-	-	-	98.184	-	-	-	98.999	0.000	-	-
15-Jan-15	-	-	-	-	98.190	-	-	-	98.987	0.000	-	-
16-Jan-15	-	-	-	-	98.200	-	-	-	98.993	0.000	-	-
17-Jan-15	-	-	-	-	98.193	-	-	-	98.992	0.000	-	-
18-Jan-15	-	-	-	-	98.200	-	-	-	98.985	0.000	-	-
19-Jan-15	-	-	-	-	98.203	-	-	-	98.975	0.000	-	-
20-Jan-15	-	-	-	-	98.205	-	-	-	98.971	0.000	-	-
21-Jan-15	-	-	-	-	98.196	-	-	-	98.970	0.000	-	-
22-Jan-15	-	-	-	-	98.197	-	-	-	98.960	0.000	-	-
23-Jan-15	-	-	-	-	98.207	-	-	-	98.956	0.000	-	-
24-Jan-15	-	-	-	-	98.209	-	-	-	98.951	0.000	-	-
25-Jan-15	-	-	-	-	98.213	-	-	-	98.948	0.000	-	-
26-Jan-15	-	-	-	-	98.211	-	-	-	98.952	0.000	-	-
27-Jan-15	-	-	-	-	98.214	-	-	-	98.941	0.000	-	-
28-Jan-15	-	-	-	-	98.225	-	-	-	98.937	0.000	-	-
29-Jan-15	-	-	-	-	98.246	-	-	-	98.905	0.000	-	-
30-Jan-15	-	-	-	-	-	-	-	-	98.930	0.000	-	-
31-Jan-15	-	-	-	-	98.255	-	-	-	98.921	0.000	-	-
01-Feb-15	-	-	-	-	98.195	-	-	-	98.945	0.000	-	-
02-Feb-15	-	-	-	-	98.202	-	-	-	98.916	0.000	-	-
03-Feb-15	-	-	-	-	98.175	-	-	-	98.885	0.000	-	-
04-Feb-15	-	-	-	-	98.159	-	-	-	98.871	0.000	-	-
05-Feb-15	-	-	-	-	-	-	-	-	98.901	0.000	-	-
06-Feb-15	-	-	-	-	-	-	-	-	98.840	0.000	-	-
07-Feb-15	-	-	-	-	-	-	-	-	98.826	0.000	-	-
08-Feb-15	-	-	-	-	-	-	-	-	98.892	0.000	-	-
09-Feb-15	-	-	-	-	-	-	-	-	98.872	0.000	-	-
10-Feb-15	-	-	-	-	-	-	-	-	98.879	0.000	-	-
11-Feb-15	-	-	-	-	-	-	-	-	98.854	0.000	-	-
12-Feb-15	-	-	-	-	-	-	-	-	98.879	0.000	-	-
13-Feb-15	-	-	-	-	-	-	-	-	98.873	0.000	-	-
14-Feb-15	-	-	-	-	-	-	-	-	98.865	0.000	-	-
15-Feb-15	-	-	-	-	-	-	-	-	98.865	0.000	-	-
16-Feb-15	-	-	-	-	-	-	-	-	98.854	0.000	-	-
17-Feb-15	-	-	-	-	-	-	-	-	98.859	0.000	-	-
18-Feb-15	-	-	-	-	-	-	-	-	98.829	0.000	-	-
19-Feb-15	-	-	-	-	-	-	-	-	98.856	0.000	-	-
20-Feb-15	-	-	-	-	-	-	-	-	98.853	0.000	-	-
21-Feb-15	-	-	-	-	-	-	-	-	98.829	0.000	-	-
22-Feb-15	-	-	-	-	-	-	-	-	98.812	0.000	-	-
23-Feb-15	-	-	-	-	-	-	-	-	98.851	0.000	-	-
24-Feb-15	-	-	-	-	-	-	-	-	98.842	0.000	-	-
25-Feb-15	-	-	-	-	-	-	-	-	98.814	0.000	-	-
26-Feb-15	-	-	-	-	-	-	-	-	98.817	0.000	-	-
27-Feb-15	-	-	-	-	-	-	-	-	98.830	0.000	-	-
28-Feb-15	-	-	-	-	-	-	-	-	98.825	0.000	-	-
01-Mar-15	-	-	-	-	-	-	-	-	98.823	0.000	-	-
02-Mar-15	-	-	-	-	-	-	-	-	98.821	0.000	-	-
03-Mar-15	-	-	-	-	-	-	-	-	98.799	0.000	-	-
04-Mar-15	-	-	-	-	-	-	-	-	98.836	0.000	-	-
05-Mar-15	-	-	-	-	-	-	-	-	98.811	0.000	-	-
06-Mar-15	-	-	-	-	-	-	-	-	98.811	0.000	-	-
07-Mar-15	-	-	-	-	-	-	-	-	98.805	0.000	-	-
08-Mar-15	-	-	-	-	-	-	-	-	98.802	0.000	-	-
09-Mar-15	-	-	-	-	-	-	-	-	98.805	0.000	-	-
10-Mar-15	-	-	-	-	-	-	-	-	98.800	0.000	-	-
11-Mar-15	-	-	-	-	-	-	-	-	98.798	0.000	-	-
12-Mar-15	-	-	-	-	-	-	-	-	98.801	0.000	-	-
13-Mar-15	-	-	-	-	-	-	-	-	98.804	0.000	-	-
14-Mar-15	-	-	-	-	-	-	-	-	98.820	0.000	-	-
15-Mar-15	-	-	-	-	-	-	-	-	98.882	0.012	-	-
16-Mar-15	-	-	-	-	-	-	-	-	98.859	0.007	-	-
17-Mar-15	-	-	-	-	-	-	-	-	98.859	0.008	-	-
18-Mar-15	-	-	-	-	-	-	-	-	98.873	0.009	-	-
19-Mar-15	-	-	-	-	-	-	-	-	98.882	0.005	-	-
20-Mar-15	-	-	-	-	-	-	-	-	98.880	0.000	-	-
21-Mar-15	-	-	-	-	-	-	-	-	98.868	0.000	-	-
22-Mar-15	-	-	-	-	-	-	-	-	98.866	0.000	-	-
23-Mar-15	-	-	-	-	-	-	-	-	98.862	0.000	-	-
24-Mar-15	-	-	-	-	-	-	-	-	98.855	0.000	-	-
25-Mar-15	-	-	-	-	-	-	-	-	98.847	0.000	-	-
26-Mar-15	-	-	-	-	-	-	-	-	98.849	0.000	-	-
27-Mar-15	-	-	-	-	-	-	-	-	98.854	0.000	-	-
28-Mar-15	-	-	-	-	-	-	-	-	98.900	0.000	-	-
29-Mar-15	-	-	-	-	-	-	-	-	98.976	0.000	-	-
30-Mar-15	-	-	-	-	-	-	-	-	99.199	0.028	-	-
31-Mar-15	-	-	99.408	-	-	-	-	-	99.529	0.483	-	-
01-Apr-15	-	-	99.036	-	-	-	-	-	99.547	0.478	-	-
02-Apr-15	-	-	98.837	-	-	-	-	-	99.535	0.503	-	-
03-Apr-15	-	-	98.763	-	-	-	-	-	99.524	0.533	-	-
04-Apr-15	-	-	98.621	-	-	-	-	-	99.438	0.369	-	-
05-Apr-15	-	-	98.552	-	-	-	-	-	99.280	0.134	-	-
06-Apr-15	-	-	98.641	-	-	-	-	-	99.225	0.096	-	-
07-Apr-15	-	-	98.753	-	-	-	-	-	99.203	0.096	-	-
08-Apr-15	-	-	98.751	-	-	-	-	-	99.229	0.152	-	-
09-Apr-15	-	-	98.520	-	-	-	-	-	99.281	0.267	-	-
10-Apr-15	-	-	98.786	-	-	-	-	-	99.407	0.636	-	-
11-Apr-15	-	-	98.779	-	-	-	-	-	99.482	0.979	-	-
12-Apr-15	-	-	98.628	-	-	-	-	-	99.519	1.232	-	-
13-Apr-15	-	-	98.509	-	-	-	-	-	99.534	1.881	-	-
14-Apr-15	-	-	98.509	-	-	-	-	-	99.627	2.220	-	-
15-Apr-15	-	-	98.415	-	-	-	-	-	99.547	2.363	-	-
16-Apr-15	-	-	98.385	-	-	-	-	-	99.472	2.338	-	-
17-Apr-15	-	-	98.455	-	-	-	-	-	99.470	2.272	-	-
18-Apr-15	-	-	98.438	-	-	-	-	-	99.489	2.184	-	-
19-Apr-15	-	-	98.415	-	-	-	-	-	99.506	2.070	-	-
20-Apr-15	-	-	98.393	-	-	-	-	-	99.522	2.018	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
21-Apr-15	-	-	98.409	-	-	-	-	-	99.508	1.821	-	-
22-Apr-15	-	-	98.313	-	-	-	-	-	99.502	1.618	-	-
23-Apr-15	-	-	98.297	-	-	-	-	-	99.493	1.411	-	-
24-Apr-15	-	-	98.267	-	-	-	-	-	99.484	1.220	-	-
25-Apr-15	-	-	98.280	-	-	-	-	-	99.468	1.020	-	-
26-Apr-15	-	-	98.273	-	-	-	-	-	99.456	0.856	-	-
27-Apr-15	-	-	98.256	-	-	-	-	-	99.452	0.736	-	-
28-Apr-15	-	-	98.287	-	-	-	-	-	99.450	0.633	-	-
29-Apr-15	-	-	98.257	-	-	-	-	-	99.444	0.527	-	-
30-Apr-15	-	-	98.257	-	-	-	-	-	99.432	0.417	-	-
01-May-15	-	-	98.255	-	-	-	-	-	99.462	0.417	-	-
02-May-15	-	-	98.249	0.027	-	-	-	-	99.475	0.377	-	-
03-May-15	-	-	98.255	0.029	-	-	-	-	99.465	0.291	-	-
04-May-15	-	-	98.246	0.027	-	-	-	-	99.081	0.236	-	-
05-May-15	-	-	98.245	0.028	-	-	-	-	99.085	0.243	-	-
06-May-15	-	-	98.258	0.031	-	-	-	-	99.070	0.218	-	-
07-May-15	-	-	98.276	0.037	-	-	-	-	99.101	0.272	-	-
08-May-15	-	-	98.286	0.040	-	-	-	-	99.125	0.320	-	-
09-May-15	-	-	98.393	0.093	-	-	-	-	99.128	0.327	-	-
10-May-15	-	-	98.417	0.120	-	-	-	-	99.144	0.362	-	-
11-May-15	-	-	98.369	0.083	-	-	-	-	99.175	0.436	-	-
12-May-15	-	-	98.376	0.089	-	-	-	-	99.189	0.473	-	-
13-May-15	-	-	98.340	0.068	-	-	-	-	99.209	0.526	-	-
14-May-15	-	-	98.331	0.064	-	-	-	-	99.220	0.557	-	-
15-May-15	-	-	98.328	0.064	-	-	-	-	99.241	0.620	-	-
16-May-15	-	-	98.313	0.058	-	-	-	-	99.261	0.683	-	-
17-May-15	-	-	98.294	0.050	-	-	-	-	99.276	0.732	-	-
18-May-15	-	-	98.286	0.048	-	-	-	-	99.251	0.651	-	-
19-May-15	-	-	98.258	0.039	-	-	-	-	99.236	0.605	-	-
20-May-15	-	-	98.245	0.036	-	-	-	-	99.231	0.590	-	-
21-May-15	-	-	98.257	0.040	-	-	-	-	99.196	0.491	-	-
22-May-15	-	-	98.252	0.039	-	-	-	-	99.188	0.470	-	-
23-May-15	-	-	98.246	0.038	-	-	-	-	99.161	0.392	-	-
24-May-15	-	-	98.237	0.034	98.711	0.034	-	-	99.146	0.340	-	-
25-May-15	-	-	98.233	0.033	98.707	0.031	-	-	99.111	0.255	-	-
26-May-15	-	-	98.234	0.032	98.694	0.023	-	-	99.086	0.201	-	-
27-May-15	-	-	98.240	0.033	98.704	0.029	97.073	11.280	99.069	0.165	-	-
28-May-15	-	-	98.228	0.030	98.705	0.030	97.066	10.948	99.080	0.170	-	-
29-May-15	-	-	98.221	0.028	98.705	0.030	97.058	10.574	99.078	0.156	-	-
30-May-15	-	-	98.216	0.026	98.698	0.025	97.051	10.253	99.080	0.149	-	-
31-May-15	-	-	98.198	0.022	98.697	0.025	97.042	9.846	99.091	0.154	-	-
01-Jun-15	-	-	98.202	0.022	98.704	0.029	97.038	9.668	99.087	0.139	-	-
02-Jun-15	-	-	98.202	0.022	98.705	0.030	97.030	9.317	99.099	0.144	-	-
03-Jun-15	-	-	98.214	0.024	98.703	0.028	97.035	9.535	99.136	0.185	-	-
04-Jun-15	-	-	98.204	0.021	98.703	0.028	97.026	9.143	99.165	0.218	-	-
05-Jun-15	-	-	98.205	0.021	98.703	0.028	97.018	8.801	99.175	0.222	-	-
06-Jun-15	-	-	98.200	0.020	98.699	0.026	97.013	8.590	99.164	0.192	-	-
07-Jun-15	-	-	98.199	0.019	98.697	0.025	97.007	8.341	99.197	0.233	-	-
08-Jun-15	-	-	98.175	0.016	98.691	0.022	97.001	8.095	99.208	0.239	-	-
09-Jun-15	-	-	98.264	0.032	98.712	0.035	97.020	8.886	99.266	0.338	-	-
10-Jun-15	-	-	98.306	0.043	98.705	0.033	97.037	9.624	99.309	0.421	-	-
11-Jun-15	-	-	98.353	0.062	98.698	0.029	97.052	10.298	99.357	0.527	-	-
12-Jun-15	-	-	98.300	0.051	98.705	0.030	97.068	11.042	99.407	0.560	-	-
13-Jun-15	-	-	98.315	0.044	98.706	0.030	97.087	11.958	99.370	0.520	-	-
14-Jun-15	-	-	98.294	0.037	98.707	0.031	97.087	11.958	99.354	0.457	-	-
15-Jun-15	-	-	98.270	0.030	98.702	0.028	97.095	12.354	99.368	0.474	-	-
16-Jun-15	-	-	98.260	0.027	98.701	0.027	97.107	12.960	99.364	0.444	-	-
17-Jun-15	-	-	98.242	0.023	98.700	0.027	97.114	13.320	99.381	0.469	-	-
18-Jun-15	-	-	98.244	0.023	98.697	0.025	97.115	13.372	99.397	0.491	-	-
19-Jun-15	-	-	98.226	0.019	98.696	0.024	97.107	12.960	99.413	0.513	-	-
20-Jun-15	-	-	98.215	0.017	98.690	0.021	97.094	12.304	99.416	0.501	-	-
21-Jun-15	-	-	98.218	0.017	98.686	0.019	97.074	11.328	99.409	0.463	-	-
22-Jun-15	-	-	98.226	0.018	98.679	0.016	97.059	10.621	99.412	0.451	-	-
23-Jun-15	-	-	98.231	0.019	98.692	0.022	97.049	10.162	99.410	0.426	-	-
24-Jun-15	-	-	98.231	0.018	98.689	0.021	97.040	9.757	99.423	0.440	-	-
25-Jun-15	-	-	98.220	0.016	98.691	0.021	97.029	9.273	99.437	0.457	-	-
26-Jun-15	-	-	98.216	0.016	98.686	0.019	97.020	8.886	99.413	0.443	-	-
27-Jun-15	-	-	98.221	0.016	98.689	0.021	97.016	8.717	99.448	0.444	-	-
28-Jun-15	-	-	98.224	0.016	98.689	0.021	97.009	8.424	99.350	0.400	-	-
29-Jun-15	-	-	98.227	0.016	98.683	0.018	97.009	8.424	99.350	0.358	-	-
30-Jun-15	-	-	98.229	0.016	98.683	0.018	97.011	8.507	99.350	0.296	-	-
01-Jul-15	-	-	98.233	0.016	98.686	0.020	96.993	7.773	99.350	0.226	-	-
02-Jul-15	-	-	98.236	0.016	98.691	0.022	96.996	7.893	99.350	0.164	-	-
03-Jul-15	-	-	98.238	0.016	98.686	0.019	96.993	7.773	99.350	0.122	-	-
04-Jul-15	-	-	98.236	0.016	98.687	0.020	96.988	7.574	99.307	0.104	-	-
05-Jul-15	-	-	98.241	0.016	98.694	0.023	96.993	7.773	99.310	0.099	-	-
06-Jul-15	-	-	98.239	0.015	98.693	0.023	96.982	7.340	99.303	0.085	-	-
07-Jul-15	-	-	98.235	0.015	98.696	0.025	96.981	7.301	99.305	0.079	-	-
08-Jul-15	-	-	98.234	0.014	98.692	0.022	96.972	6.952	99.308	0.075	-	-
09-Jul-15	-	-	98.230	0.014	98.690	0.021	96.975	7.066	99.306	0.067	-	-
10-Jul-15	-	-	98.235	0.014	98.701	0.027	96.972	6.952	99.308	0.062	-	-
11-Jul-15	-	-	98.230	0.013	98.693	0.023	96.976	7.104	99.297	0.048	-	-
12-Jul-15	-	-	98.227	0.013	98.679	0.017	96.970	6.877	99.286	0.037	-	-
13-Jul-15	-	-	98.261	0.016	98.692	0.022	96.977	7.142	99.299	0.040	-	-
14-Jul-15	-	-	98.669	0.104	98.699	0.026	97.082	11.714	99.327	0.054	-	-
15-Jul-15	-	-	98.619	0.079	98.700	0.027	97.144	14.917	99.324	0.046	-	-
16-Jul-15	-	-	98.541	0.067	98.683	0.018	97.176	16.716	99.333	0.047	-	-
17-Jul-15	-	-	98.463	0.059	98.691	0.022	97.186	17.298	99.354	0.057	-	-
18-Jul-15	-	-	98.422	0.053	98.688	0.020	97.187	17.357	99.417	0.108	-	-
19-Jul-15	-	-	98.410	0.051	98.692	0.022	97.190	17.534	99.449	0.136	-	-
20-Jul-15	-	-	98.401	0.050	98.710	0.034	97.194	17.771	99.457	0.136	-	-
21-Jul-15	-	-	98.371	0.039	98.700	0.027	97.212	18.857	99.450	0.123	-	-
22-Jul-15	-	-	98.361	0.036	98.708	0.033	97.190	17.534	99.460	0.134	-	-
23-Jul-15	-	-	98.346	0.032	98.702	0.028	97.175	16.658	99.457	0.130	-	-
24-Jul-15	-	-	98.341	0.031	98.698	0.026	97.166	16.143	99.452	0.124	-	-
25-Jul-15	-	-	98.335	0.029	98.692	0.022	97.161	15.860	99.441	0.110	-	-
26-Jul-15	-	-	98.332	0.028	98.699	0.026	97.137	14.536	99.435	0.103	-	-
27-Jul-15	-	-	98.333	0.027	98.701	0.027	97.128	14.054	99.426	0.093	-	-
28-Jul-15	-	-	98.336	0.027	98.712	0.035	97.134	14.375	99.423	0.090	-	-
29-Jul-15	-	-	98.330	0.025	98.714	0.037	97.123	13.790	99.429	0.095	-	-
30-Jul-15	-	-	98.337	0.026	98.713	0.035	97.108	13.011	99.445	0.112	-	-
31-Jul-15	-	-	98.335	0.025	98.760	0.050	97.123	13.790	99.445	0.111	-	-
01-Aug-15	-	-	98.338	0.025	98.729	0.041	97.098	12.504	99.442	0.107	-	-
02-Aug-15	-	-	98.340	0.024	98.720	0.039	97.088	12.007	99.443	0.108	-	-
03-Aug-15	-	-	98.328	0.021	98.713	0.034	97.073	11.280	99.447	0.112	-	-
04-Aug-15	-	-	98.332	0.022	98.708	0.030	97.061	10.714	99.448	0.112	-	-
05-Aug-15	-	-	98.336	0.021	98.710	0.032	97.053	10.344	99.473	0.141	-	-
06-Aug-15	-	-	98.344	0.022	98.702	0.026	97.041	9.801	99.479	0.148	-	-
07-Aug-15	-	-	98.349	0.023	98.734	0.041	97.031	9.360	99.487	0.158	-	-
08-Aug-15	-	-	98.360	0.024	98.730	0.040	97.026	9.143	99.491	0.163	-	-
09-Aug-15	-	-	98.358	0.023	98.719	0.037	97.027	9.186	99.488	0.158	-	-
10-Aug-15	-	-	98.361	0.023	98.713	0.034	97.031	9.360	99.489	0.158	-	-
11-Aug-15	-	-	98.362	0.022	98.699	0.023	97.037	9.624	99.486	0.154	-	-
12-Aug-15	-	-	98.358	0.021	98.668	0.013	97.040	9.757	99.486	0.153	-	-
13-Aug-15	-	-	98.357	0.020	98.689	0.017	97.026	9.143	99.485	0.151	-	-
14-Aug-15	-	-	98.358	0.020	98.694	0.020	97.018	8.801	99.487	0.153	-	-
15-Aug-15	-	-	98.357	0.019	98.690	0.018	97.002	8.136	99.483	0.147	-	-
16-Aug-15	-	-	98.357	0.018	98.688	0.016	96.997	7.933	99.482	0.145	-	-
17-Aug-15	-	-	98.358	0.018	98.689	0.017	96.992	7.733	99.486	0.149	-	-
18-Aug-15	-	-	98.353	0.017	98.679	0.012	96.984	7.418	99.481	0.142	-	-
19-Aug-15	-	-	98.349	0.016	98.677	0.011	96.979	7.224	99.482	0.143	-	-
20-Aug-15	-	-	98.333	0.013	98.678	0.011	96.972	6.957	99.487	0.148	-	-
21-Aug-15	-	-	98.331	0.013	98.672	0.009	96.968	6.806	99.487	0.148	-	-
22-Aug-15	-	-	98.333	0.013	98.673	0.009	96.965	6.694	99.488	0.149	-	-
23-Aug-15	-	-	98.309	0.010	98.679	0.011	96.966	6.732	99.486	0.146	-	-
24-Aug-15	-	-	98.305	0.010	98.674	0.009	96.962	6.584	99.485	0.144	-	-
25-Aug-15	-	-	98.301	0.009	98.678	0.011	96.962	6.584	99.482	0.139	-	-
26-Aug-15	-	-	98.303	0.009	98.673	0.009	96.957	6.401	99.479	0.135	-	-
27-Aug-15	-	-	98.301	0.008	98.679	0.011	96.965	6.694	99.482	0.138	-	-
28-Aug-15	-	-	98.297	0.008	98.679	0.010	96.956	6.364	99.486	0.142	-	-
29-Aug-15	-	-	98.275	0.006	98.667	0.007	96.946	6.007	99.486	0.142	-	-
30-Aug-15	-	-	98.257	0.005	98.675	0.009	96.945	5.972	99.482	0.136	-	-
31-Aug-15	-	-	98.237	0.004	98.698	0.019	96.950	6.149	99.477	0.129	-	-
01-Sep-15	-	-	98.208	0.003	98.688	0.013	96.940	5.798	99.481	0.133	-	-
02-Sep-15	-	-	98.359	0.011	98.763	0.045	96.996	7.893	99.525	0.192	-	-
03-Sep-15	-	-	98.364	0.011	98.748	0.041	97.013	8.590	99.532	0.202	-	-
04-Sep-15	-	-	98.533	0.043	98.773	0.048	97.077	11.472	99.575	0.275	-	-
05-Sep-15	-	-	98.436	0.019	98.764	0.045	97.113	13.268	99.601	0.327	-	-
06-Sep-15	-	-	98.430	0.018	98.754	0.042	97.127	14.001	99.603	0.330	-	-
07-Sep-15	-	-	98.449	0.020	98.744	0.039	97.130	14.161	99.599	0.320	-	-
08-Sep-15	-	-	98.458	0.021	98.737	0.037	97.129	14.107	99.591	0.302	-	-
09-Sep-15	-	-	98.481	0.024	98.720	0.032	97.118	13.528	99.584	0.287	-	-
10-Sep-15	-	-	98.490	0.025	98.729	0.034	97.117	13.476	99.590	0.298	-	-
11-Sep-15	-	-	98.489	0.024	98.722	0.032	97.105	12.858	99.592	0.301	-	-
12-Sep-15	-	-	98.498	0.025	98.708	0.024	97.099	12.555	99.590	0.296	-	-
13-Sep-15	-	-	98.501	0.025	98.703	0.020	97.088	12.007	99.596	0.307	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
14-Sep-15	-	-	98.503	0.025	98.723	0.032	97.082	11.714	99.596	0.306	-	-
15-Sep-15	-	-	98.523	0.028	98.723	0.032	97.070	11.137	99.596	0.305	-	-
16-Sep-15	-	-	98.515	0.026	98.714	0.029	97.062	10.760	99.598	0.308	-	-
17-Sep-15	-	-	98.546	0.032	98.708	0.023	97.059	10.621	99.595	0.300	-	-
18-Sep-15	-	-	98.552	0.033	98.701	0.018	97.050	10.207	99.590	0.289	-	-
19-Sep-15	-	-	98.538	0.028	98.701	0.018	97.044	9.936	99.586	0.280	-	-
20-Sep-15	-	-	98.537	0.027	98.701	0.018	97.041	9.801	99.587	0.281	-	-
21-Sep-15	-	-	98.535	0.026	98.699	0.016	97.029	9.273	99.577	0.261	-	-
22-Sep-15	-	-	98.573	0.034	98.714	0.027	97.030	9.317	99.576	0.258	-	-
23-Sep-15	-	-	98.613	0.046	98.715	0.028	97.030	9.317	99.574	0.254	-	-
24-Sep-15	-	-	98.619	0.047	98.715	0.028	97.025	9.100	99.584	0.271	-	-
25-Sep-15	-	-	98.613	0.043	98.713	0.026	97.021	8.929	99.582	0.266	-	-
26-Sep-15	-	-	98.605	0.040	98.712	0.025	97.019	8.843	99.590	0.281	-	-
27-Sep-15	-	-	98.609	0.040	98.717	0.028	97.019	8.843	99.592	0.284	-	-
28-Sep-15	-	-	98.617	0.041	98.720	0.029	97.016	8.717	99.592	0.282	-	-
29-Sep-15	-	-	98.598	0.034	98.720	0.029	97.015	8.674	99.591	0.279	-	-
30-Sep-15	-	-	98.602	0.034	98.723	0.029	97.014	8.632	99.592	0.280	-	-
01-Oct-15	-	-	98.601	0.033	98.717	0.028	97.008	8.382	99.594	0.283	-	-
02-Oct-15	-	-	98.610	0.035	98.712	0.024	97.009	8.424	99.596	0.286	-	-
03-Oct-15	-	-	98.617	0.035	98.718	0.028	97.011	8.507	99.596	0.285	-	-
04-Oct-15	-	-	98.599	0.030	98.719	0.028	97.010	8.465	99.593	0.278	-	-
05-Oct-15	-	-	98.602	0.030	98.724	0.029	97.014	8.632	99.597	0.285	-	-
06-Oct-15	-	-	98.583	0.025	98.718	0.027	97.011	8.507	99.603	0.296	-	-
07-Oct-15	-	-	98.574	0.022	98.719	0.027	97.009	8.424	99.605	0.299	-	-
08-Oct-15	-	-	98.587	0.024	98.721	0.027	97.011	8.507	99.607	0.301	-	-
09-Oct-15	-	-	98.607	0.027	98.722	0.027	97.007	8.341	99.612	0.311	-	-
10-Oct-15	-	-	98.618	0.029	98.721	0.027	97.009	8.424	99.611	0.307	-	-
11-Oct-15	-	-	98.610	0.026	98.717	0.026	97.009	8.424	99.617	0.319	-	-
12-Oct-15	-	-	98.603	0.024	98.720	0.026	97.010	8.465	99.624	0.332	-	-
13-Oct-15	-	-	98.598	0.023	98.714	0.024	97.013	8.590	99.633	0.351	-	-
14-Oct-15	-	-	98.596	0.022	98.704	0.016	97.003	8.177	99.634	0.352	-	-
15-Oct-15	-	-	98.597	0.021	98.714	0.024	97.005	8.259	99.634	0.351	-	-
16-Oct-15	-	-	98.589	0.019	98.714	0.023	97.008	8.382	99.635	0.352	-	-
17-Oct-15	-	-	98.573	0.016	98.707	0.017	97.001	8.095	99.636	0.353	-	-
18-Oct-15	-	-	98.576	0.015	98.701	0.013	96.997	7.933	99.638	0.356	-	-
19-Oct-15	-	-	98.549	0.013	98.716	0.024	96.998	7.973	99.641	0.361	-	-
20-Oct-15	-	-	98.577	0.015	98.714	0.023	97.005	8.259	99.648	-	-	-
21-Oct-15	-	-	98.607	0.019	98.718	0.024	97.007	8.341	99.660	-	-	-
22-Oct-15	-	-	98.596	0.017	98.719	0.025	97.010	8.465	99.665	-	-	-
23-Oct-15	-	-	98.597	0.017	98.709	0.018	97.014	8.632	99.670	-	-	-
24-Oct-15	-	-	98.586	0.015	98.723	0.025	97.017	8.759	99.674	-	-	-
25-Oct-15	-	-	98.609	0.015	98.717	0.023	97.021	8.929	99.684	-	-	-
26-Oct-15	-	-	98.586	0.014	98.717	0.023	97.017	8.759	99.694	-	-	-
27-Oct-15	-	-	98.592	0.014	98.726	0.025	97.022	8.971	-	-	-	-
28-Oct-15	-	-	98.601	0.015	98.733	0.027	97.039	9.712	-	-	-	-
29-Oct-15	-	-	98.598	0.014	98.731	0.026	97.061	10.714	-	-	-	-
30-Oct-15	-	-	98.602	0.014	98.733	0.027	97.062	10.760	-	-	-	-
31-Oct-15	-	-	98.601	0.014	98.732	0.026	97.049	11.104	-	-	-	-
01-Nov-15	-	-	98.608	0.014	98.721	0.023	97.066	10.948	-	-	-	-
02-Nov-15	-	-	98.569	0.010	98.721	0.023	97.071	11.184	-	-	-	-
03-Nov-15	-	-	98.563	0.009	98.726	0.024	97.062	10.760	-	-	-	-
04-Nov-15	-	-	98.564	0.009	98.722	0.023	97.053	10.381	-	-	-	-
05-Nov-15	-	-	98.565	0.009	98.725	0.023	97.033	9.877	-	-	-	-
06-Nov-15	-	-	98.558	0.008	98.724	0.023	97.088	9.707	-	-	-	-
07-Nov-15	-	-	98.557	0.008	98.723	0.023	96.998	8.917	99.505	-	-	-
08-Nov-15	-	-	98.560	0.008	98.724	0.023	97.083	8.849	99.501	-	-	-
09-Nov-15	-	-	98.552	0.007	98.722	0.022	97.049	8.294	99.496	-	-	-
10-Nov-15	-	-	98.551	0.007	98.713	0.018	97.132	8.237	99.495	-	-	-
11-Nov-15	-	-	98.553	0.007	98.715	0.020	97.104	7.696	99.500	-	-	-
12-Nov-15	-	-	98.553	0.006	98.714	0.019	97.135	7.416	99.499	-	-	-
13-Nov-15	-	-	98.550	0.006	98.712	0.017	97.106	6.879	99.497	-	-	-
14-Nov-15	-	-	98.551	0.006	98.711	0.016	97.167	6.727	99.497	-	-	-
15-Nov-15	-	-	98.551	0.006	98.655	0.010	97.166	6.306	99.494	-	-	-
16-Nov-15	-	-	98.545	0.005	98.665	0.014	97.201	6.047	99.491	0.014	-	-
17-Nov-15	-	-	98.547	0.005	98.660	0.014	97.188	5.572	99.490	0.015	-	-
18-Nov-15	-	-	98.548	0.005	98.667	0.018	97.171	5.307	99.491	0.016	-	-
19-Nov-15	-	-	98.543	0.005	98.666	0.019	97.173	5.344	99.489	0.016	-	-
20-Nov-15	-	-	98.534	0.004	98.660	0.018	97.175	5.382	99.485	0.016	-	-
21-Nov-15	-	-	98.541	0.004	98.660	0.020	97.177	5.419	99.482	0.016	-	-
22-Nov-15	-	-	98.545	0.004	98.664	0.024	97.180	5.457	99.485	0.018	-	-
23-Nov-15	-	-	98.544	0.004	98.663	0.026	97.182	5.494	99.482	0.018	-	-
24-Nov-15	-	-	98.542	0.004	98.663	0.028	97.184	5.532	99.479	0.018	-	-
25-Nov-15	-	-	98.541	0.004	98.663	0.031	97.186	5.569	99.482	0.020	-	-
26-Nov-15	-	-	98.540	0.004	98.663	0.034	97.188	5.607	98.481	0.020	-	-
27-Nov-15	-	-	98.541	0.004	98.653	0.029	97.190	5.644	99.480	0.021	-	-
28-Nov-15	-	-	98.538	0.004	98.653	0.032	97.192	5.682	99.477	0.021	-	-
29-Nov-15	-	-	98.539	0.004	98.651	0.034	97.194	5.719	99.471	0.020	-	-
30-Nov-15	-	-	98.539	0.004	98.750	0.070	97.196	5.757	99.476	0.022	-	-
01-Dec-15	-	-	98.539	0.004	98.689	0.050	97.199	5.794	99.481	0.024	-	-
02-Dec-15	-	-	98.537	0.004	98.694	0.053	97.201	5.832	99.486	0.027	-	-
03-Dec-15	-	-	98.542	0.004	-	-	97.203	5.869	99.488	0.028	-	-
04-Dec-15	-	-	98.543	0.004	-	-	97.205	5.907	99.499	0.035	-	-
05-Dec-15	-	-	98.539	0.004	-	-	97.207	5.944	99.498	0.036	-	-
06-Dec-15	-	-	98.535	0.004	-	-	97.209	5.982	99.450	0.020	-	-
07-Dec-15	-	-	98.534	0.004	-	-	97.211	6.019	99.387	0.001	-	-
08-Dec-15	-	-	98.535	0.004	-	-	97.213	6.057	99.383	0.001	-	-
09-Dec-15	-	-	98.536	0.004	-	-	97.216	6.094	99.379	0.001	-	-
10-Dec-15	-	-	98.535	0.004	-	-	97.218	6.132	99.393	0.006	-	-
11-Dec-15	-	-	98.534	0.004	-	-	97.220	6.169	99.446	0.023	-	-
12-Dec-15	-	-	98.533	0.004	-	-	97.222	6.207	99.417	0.015	-	-
13-Dec-15	-	-	98.534	0.004	-	-	97.224	6.244	99.391	0.008	-	-
14-Dec-15	-	-	98.532	0.004	-	-	97.226	6.281	99.363	0.000	-	-
15-Dec-15	-	-	98.531	0.004	-	-	97.228	6.319	99.356	0.000	-	-
16-Dec-15	-	-	98.532	0.004	-	-	97.230	6.356	99.350	0.000	-	-
17-Dec-15	-	-	98.516	0.004	-	-	97.232	6.394	99.346	0.000	-	-
18-Dec-15	-	-	98.486	0.003	-	-	97.235	6.431	99.355	0.001	-	-
19-Dec-15	-	-	98.468	0.002	-	-	97.237	6.469	99.335	0.000	-	-
20-Dec-15	-	-	98.452	0.002	-	-	97.239	6.506	99.329	0.000	-	-
21-Dec-15	-	-	98.476	0.003	-	-	97.241	6.544	99.330	0.000	-	-
22-Dec-15	-	-	98.461	0.002	-	-	97.243	6.581	99.319	0.000	-	-
23-Dec-15	-	-	98.477	0.003	-	-	97.245	6.619	99.293	0.000	-	-
24-Dec-15	-	-	98.433	0.002	-	-	97.247	6.656	99.299	0.000	-	-
25-Dec-15	-	-	98.405	0.002	-	-	97.249	6.694	99.302	0.000	-	-
26-Dec-15	-	-	98.407	0.002	-	-	97.252	6.731	99.287	0.000	-	-
27-Dec-15	-	-	98.416	0.002	-	-	97.254	6.769	99.292	0.000	-	-
28-Dec-15	-	-	98.394	0.001	-	-	97.256	6.806	99.293	0.000	-	-
29-Dec-15	-	-	98.385	0.001	-	-	97.258	6.844	99.295	0.000	-	-
30-Dec-15	-	-	98.381	0.001	-	-	97.260	6.881	99.292	0.000	-	-
31-Dec-15	-	-	98.377	0.001	-	-	97.262	6.919	99.290	0.000	-	-
01-Jan-16	-3.5	-	98.370	0.001	-	-	97.264	6.956	99.285	0.000	-	-
02-Jan-16	-6.5	-	98.387	0.001	-	-	97.266	6.994	99.285	0.000	-	-
03-Jan-16	-12.6	-	98.410	0.002	-	-	97.268	7.031	99.310	0.002	-	-
04-Jan-16	-14.5	-	98.417	0.002	-	-	97.271	7.069	99.303	0.001	-	-
05-Jan-16	-14.3	-	98.398	0.002	-	-	97.273	7.106	99.296	0.000	-	-
06-Jan-16	-17.5	-	98.380	0.001	-	-	97.275	7.144	99.288	0.000	-	-
07-Jan-16	-16.0	-	98.370	0.001	-	-	97.277	7.181	99.276	0.000	-	-
08-Jan-16	-18.8	-	98.356	0.001	-	-	97.279	7.219	99.269	0.000	-	-
09-Jan-16	-23.5	-	98.353	0.001	-	-	97.281	7.256	99.265	0.000	-	-
10-Jan-16	-18.5	-	98.352	0.001	-	-	97.283	7.294	99.259	0.000	-	-
11-Jan-16	-18.6	-	98.351	0.001	-	-	97.285	7.331	99.246	0.000	-	-
12-Jan-16	-18.0	-	98.352	0.001	-	-	97.288	7.369	99.249	0.000	-	-
13-Jan-16	-12.3	-	98.349	0.001	-	-	97.290	7.406	99.256	0.000	-	-
14-Jan-16	-18.1	-	98.345	0.001	-	-	97.292	7.444	99.249	0.000	-	-
15-Jan-16	-23.1	-	98.334	0.001	-	-	97.294	7.481	99.249	0.000	-	-
16-Jan-16	-31.1	-	98.322	0.001	-	-	97.296	7.519	99.249	0.000	-	-
17-Jan-16	-26.8	-	98.306	0.001	-	-	97.298	7.556	99.248	0.000	-	-
18-Jan-16	-15.8	-	98.290	0.001	-	-	97.300	7.594	99.247	0.000	-	-
19-Jan-16	-14.1	-	98.276	0.001	-	-	97.302	7.631	99.222	0.000	-	-
20-Jan-16	-14.5	-	98.264	0.001	-	-	97.304	7.669	99.212	0.000	-	-
21-Jan-16	-12.2	-	98.252	0.001	-	-	97.307	7.706	99.214	0.000	-	-
22-Jan-16	-10.5	-	98.244	0.000	-	-	97.309	7.744	99.228	0.000	-	-
23-Jan-16	-9.8	-	98.237	0.000	-	-	97.311	7.781	99.223	0.000	-	-
24-Jan-16	-7.3	-	98.237	0.000	-	-	97.313	7.819	99.218	0.000	-	-
25-Jan-16	-8.6	-	98.236	0.000	-	-	97.315	7.856	99.226	0.000	-	-
26-Jan-16	-4.8	-	98.235	0.000	-	-	97.317	7.894	99.216	0.000	-	-
27-Jan-16	1.6	-	98.234	0.000	-	-	97.319	7.931	99.223	0.000	-	-
28-Jan-16	0.2	-	98.233	0.000	-	-	97.321	7.969	99.231	0.000	-	-
29-Jan-16	2.3	-	98.237	0.000	-	-	97.324	8.006	99.241	0.004	-	-
30-Jan-16	-4.5	-	98.242	0.000	-	-	97.326	8.044	99.237	0.003	-	-
31-Jan-16	-12.2	-	98.243	0.001	-	-	97.328	8.081	99.231	0.002	-	-
01-Feb-16	-16.2	-	98.245	0.001	-	-	97.330	8.119	99.236	0.005	-	-
02-Feb-16	-14.2	-	98.249	0.001	-	-	97.332	8.156	99.238	0.006	-	-
03-Feb-16	-14.3	-	98.248	0.001	-	-	97.334	8.194	99.236	0.006	-	-
04-Feb-16	-14.4	-	98.243	0.001	-	-	97.336	8.231	99.237	0.008	-	-
05-Feb-16	-7.7	-	98.236	0.000	-	-	97.338	8.269	99.243	0.010	-	-
06-Feb-16	-5.4	-	98.230	0.000	-	-	97.340	8.306	99.243	0.011	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
07-Feb-16	-13.0	-	98.225	0.000	-	-	97.343	8.344	99.241	0.012	-	-
08-Feb-16	-7.2	-	98.219	0.000	-	-	97.345	8.381	99.245	0.014	-	-
09-Feb-16	-3.7	-	98.213	0.000	-	-	97.347	8.419	99.240	0.013	-	-
10-Feb-16	-13.7	-	98.210	0.000	-	-	97.349	8.456	99.241	0.014	-	-
11-Feb-16	-16.0	-	98.204	0.000	-	-	97.351	8.494	99.245	0.016	-	-
12-Feb-16	-15.8	-	98.199	0.000	-	-	97.353	8.531	99.245	0.017	-	-
13-Feb-16	-8.2	-	98.187	0.000	-	-	97.355	8.569	99.236	0.015	-	-
14-Feb-16	-5.5	-	98.183	0.000	-	-	97.357	8.606	99.236	0.016	-	-
15-Feb-16	-9.1	-	98.176	0.000	-	-	97.360	8.644	99.233	0.016	-	-
16-Feb-16	-5.8	-	98.171	0.000	-	-	97.362	8.681	99.223	0.014	-	-
17-Feb-16	-11.1	-	98.168	0.000	-	-	97.364	8.719	99.227	0.016	-	-
18-Feb-16	-6.9	-	98.163	0.000	-	-	97.366	8.756	99.227	0.017	-	-
19-Feb-16	-15.0	-	98.163	0.000	-	-	97.368	8.794	99.224	0.017	-	-
20-Feb-16	-16.8	-	98.158	0.000	-	-	97.370	8.831	99.204	0.012	-	-
21-Feb-16	-7.8	-	98.154	0.000	-	-	97.372	8.869	99.210	0.015	-	-
22-Feb-16	-6.2	-	98.152	0.000	-	-	97.374	8.906	99.203	0.013	-	-
23-Feb-16	-3.7	-	98.149	0.000	-	-	97.376	8.944	-	-	-	-
24-Feb-16	-4.4	-	98.149	0.000	-	-	97.379	8.981	-	-	-	-
25-Feb-16	1.6	-	98.144	0.000	-	-	97.381	9.019	-	-	-	-
26-Feb-16	1.2	-	98.142	0.000	-	-	97.383	9.056	-	-	-	-
27-Feb-16	-9.7	-	98.139	0.000	-	-	97.385	9.094	-	-	-	-
28-Feb-16	-20.0	-	98.138	0.000	-	-	97.387	9.131	-	-	-	-
29-Feb-16	-19.3	-	98.136	0.000	-	-	97.389	9.169	-	-	-	-
01-Mar-16	-7.8	-	98.131	0.000	-	-	97.391	9.206	-	-	-	-
02-Mar-16	-7.0	-	98.124	0.000	-	-	97.393	9.244	-	-	-	-
03-Mar-16	-7.9	-	98.117	0.000	-	-	97.396	9.281	-	-	-	-
04-Mar-16	-8.3	-	98.114	0.000	-	-	97.398	9.319	-	-	-	-
05-Mar-16	-4.9	-	98.111	0.000	-	-	97.400	9.356	-	-	-	-
06-Mar-16	-6.6	-	98.109	0.000	-	-	97.402	9.394	-	-	-	-
07-Mar-16	-4.7	-	98.109	0.000	-	-	97.404	9.431	-	-	-	-
08-Mar-16	-4.7	-	98.111	0.000	-	-	97.406	9.469	-	-	-	-
09-Mar-16	-2.8	-	98.115	0.000	-	-	97.408	9.506	-	-	-	-
10-Mar-16	-2.2	-	98.113	0.000	-	-	97.410	9.544	-	-	-	-
11-Mar-16	-0.5	-	98.115	0.000	-	-	97.412	9.581	-	-	-	-
12-Mar-16	0.9	-	98.112	0.000	-	-	97.415	9.619	-	-	-	-
13-Mar-16	1.0	-	98.114	0.000	-	-	97.417	9.656	-	-	-	-
14-Mar-16	-3.3	-	98.118	0.000	-	-	97.419	9.694	-	-	-	-
15-Mar-16	-4.7	-	98.117	0.000	-	-	97.421	9.731	-	-	-	-
16-Mar-16	-7.5	-	98.117	0.000	-	-	97.423	9.769	-	-	-	-
17-Mar-16	-6.9	-	98.117	0.000	-	-	97.425	9.806	-	-	-	-
18-Mar-16	-4.5	-	98.117	0.000	-	-	97.427	9.844	-	-	-	-
19-Mar-16	-2.7	-	98.122	0.000	-	-	97.429	9.881	-	-	-	-
20-Mar-16	-1.4	-	98.126	0.000	-	-	97.432	9.919	-	-	-	-
21-Mar-16	-4.4	-	98.131	0.000	-	-	97.434	9.956	-	-	-	-
22-Mar-16	-5.6	-	98.134	0.000	-	-	97.436	9.994	-	-	-	-
23-Mar-16	-4.7	-	98.139	0.000	-	-	97.457	11.296	-	-	-	-
24-Mar-16	-9.0	-	98.141	0.000	-	-	97.469	12.782	-	-	-	-
25-Mar-16	-5.2	-	98.143	0.001	-	-	97.481	14.356	-	-	-	-
26-Mar-16	-2.6	-	98.144	0.001	-	-	97.487	15.681	-	-	-	-
27-Mar-16	0.4	-	98.146	0.001	-	-	97.483	16.483	-	-	-	-
28-Mar-16	3.4	-	98.152	0.001	-	-	97.502	18.681	-	-	-	-
29-Mar-16	4.9	-	98.168	0.001	-	-	97.519	20.883	-	-	-	-
30-Mar-16	4.0	-	98.188	0.001	-	-	97.525	22.465	-	-	-	-
31-Mar-16	-1.5	-	98.198	0.001	-	-	97.509	22.609	-	-	-	-
01-Apr-16	0.2	-	98.227	0.002	-	-	-	-	-	-	-	-
02-Apr-16	-0.3	-	98.368	0.006	-	-	-	-	-	-	-	-
03-Apr-16	-5.2	-	98.352	0.006	-	-	-	-	-	-	-	-
04-Apr-16	-0.8	-	98.347	0.006	-	-	-	-	-	-	-	-
05-Apr-16	1.9	-	98.348	0.006	-	-	-	-	-	-	-	-
06-Apr-16	0.1	-	98.349	0.007	-	-	-	-	-	-	-	-
07-Apr-16	-3.6	-	98.351	0.008	-	-	-	-	-	-	-	-
08-Apr-16	-0.2	-	98.358	0.009	-	-	-	-	-	-	-	-
09-Apr-16	-1.3	-	98.345	0.008	-	-	-	-	-	-	-	-
10-Apr-16	-4.9	-	98.334	0.008	-	-	-	-	-	-	-	-
11-Apr-16	2.0	0	98.339	0.009	-	-	-	-	-	-	-	-
12-Apr-16	4.7	0	98.340	0.010	-	-	-	-	-	-	-	-
13-Apr-16	2.7	4	98.394	0.016	-	-	-	-	-	-	-	-
14-Apr-16	-0.4	1	98.673	0.163	-	-	-	-	-	-	-	-
15-Apr-16	2.1	1.6	98.584	0.086	-	-	-	-	-	-	-	-
16-Apr-16	9.1	0.2	98.725	0.208	-	-	-	-	-	-	-	-
17-Apr-16	10.8	0	98.778	0.232	-	-	-	-	-	-	-	-
18-Apr-16	17.3	0	98.871	0.278	-	-	-	-	-	-	-	-
19-Apr-16	16.7	0	99.168	0.478	-	-	-	-	-	-	-	-
20-Apr-16	-0.1	0	98.955	0.333	-	-	-	-	-	-	-	-
21-Apr-16	2.4	0	98.874	0.293	-	-	-	-	-	-	-	-
22-Apr-16	3.5	0	98.768	0.246	-	-	-	-	-	-	-	-
23-Apr-16	6.0	0	98.737	0.237	-	-	-	-	-	-	-	-
24-Apr-16	6.9	0	98.705	0.227	-	-	-	-	-	-	-	-
25-Apr-16	4.9	0	98.714	0.234	-	-	-	-	-	-	-	-
26-Apr-16	5.5	1.4	98.708	0.235	-	-	-	-	-	-	-	-
27-Apr-16	7.2	0	98.717	0.243	-	-	-	-	-	-	-	-
28-Apr-16	11.7	0	98.717	0.247	-	-	-	-	-	-	-	-
29-Apr-16	14.7	0	98.694	0.241	-	-	-	-	-	-	-	-
30-Apr-16	13.4	0	98.694	0.244	-	-	-	-	-	-	-	-
01-May-16	14.2	0	98.686	0.245	-	-	-	-	-	-	-	-
02-May-16	17.4	0	98.680	0.246	-	-	-	-	-	-	-	-
03-May-16	22.2	0	98.652	0.237	-	-	-	-	-	-	-	-
04-May-16	21.6	0	98.666	0.247	-	-	-	-	-	-	-	-
05-May-16	15.1	0	98.661	0.249	-	-	-	-	-	-	-	-
06-May-16	12.2	0	98.647	0.247	-	-	-	-	-	-	-	-
07-May-16	16.3	0	98.630	0.243	-	-	-	-	-	-	-	-
08-May-16	13.3	0	98.620	0.242	-	-	-	-	-	-	-	-
09-May-16	6.8	0.8	98.614	0.244	-	-	-	-	-	-	-	-
10-May-16	8.1	0	98.609	0.245	-	-	-	-	-	-	-	-
11-May-16	6.0	0	98.598	0.242	-	-	-	-	-	-	-	-
12-May-16	6.9	0	98.626	0.252	-	-	-	-	-	-	-	-
13-May-16	8.8	0	98.610	0.242	-	-	-	-	-	-	-	-
14-May-16	11.4	0	98.645	0.255	-	-	-	-	-	-	-	-
15-May-16	13.4	0	98.661	0.259	-	-	-	-	-	-	-	-
16-May-16	18.3	0	98.648	0.250	-	-	-	-	-	-	-	-
17-May-16	19.4	0	98.634	0.241	-	-	-	-	-	-	-	-
18-May-16	17.3	0	98.624	0.234	-	-	-	-	-	-	-	-
19-May-16	7.7	0	98.617	0.229	-	-	-	-	-	-	-	-
20-May-16	10.4	0	98.616	0.226	-	-	-	-	-	-	-	-
21-May-16	9.3	1.4	98.607	0.220	-	-	-	-	-	-	-	-
22-May-16	9.5	0.4	98.608	0.218	-	-	-	-	-	-	-	-
23-May-16	12.3	0	98.607	0.215	-	-	-	-	-	-	-	-
24-May-16	14.4	0	98.589	0.206	-	-	-	-	-	-	-	-
25-May-16	15.4	0	98.586	0.203	-	-	-	-	-	-	-	-
26-May-16	12.6	0.4	98.581	0.199	-	-	-	-	-	-	-	-
27-May-16	13.1	0.6	98.588	0.199	-	-	-	-	-	-	-	-
28-May-16	14.3	2	98.578	0.193	-	-	-	-	-	-	-	-
29-May-16	12.6	7.2	98.589	0.195	-	-	-	-	-	-	-	-
30-May-16	13.1	0.2	98.613	0.201	-	-	-	-	-	-	-	-
31-May-16	14.0	0	98.612	0.198	-	-	-	-	-	-	-	-
01-Jun-16	13.2	0	98.600	0.192	-	-	-	-	-	-	-	-
02-Jun-16	13.4	0	98.589	0.174	-	-	-	-	-	-	-	-
03-Jun-16	16.9	3.2	98.555	0.126	-	-	-	-	-	-	-	-
04-Jun-16	18.4	0	98.543	0.109	-	-	-	-	-	-	-	-
05-Jun-16	17.6	0	98.527	0.091	-	-	-	-	-	-	-	-
06-Jun-16	21.4	16.4	98.520	0.082	-	-	-	-	-	-	-	-
07-Jun-16	22.7	2	98.598	0.145	-	-	-	-	-	-	-	-
08-Jun-16	17.3	0	98.533	0.082	-	-	-	-	-	-	-	-
09-Jun-16	12.2	32	98.511	0.065	-	-	-	-	-	-	-	-
10-Jun-16	15.4	0.2	98.840	0.266	-	-	-	-	-	-	-	-
11-Jun-16	13.3	4.2	98.686	0.200	-	-	-	-	-	-	-	-
12-Jun-16	13.3	6.2	98.681	0.196	-	-	-	-	-	-	-	-
13-Jun-16	16.7	1.6	98.678	0.193	-	-	-	-	-	-	-	-
14-Jun-16	17.9	1.2	98.653	0.159	-	-	-	-	-	-	-	-
15-Jun-16	14.1	9.4	98.626	0.122	-	-	-	-	-	-	-	-
16-Jun-16	14.4	2	98.705	0.196	-	-	-	-	-	-	-	-
17-Jun-16	13.4	11.8	98.643	0.126	-	-	-	-	-	-	-	-
18-Jun-16	14.1	0.2	98.684	0.167	-	-	-	-	-	-	-	-
19-Jun-16	15.0	0	98.658	0.129	-	-	-	-	-	-	-	-
20-Jun-16	15.9	0	98.616	0.087	-	-	-	-	-	-	-	-
21-Jun-16	20.5	0	98.587	0.066	-	-	-	-	-	-	-	-
22-Jun-16	20.7	0	98.559	0.050	-	-	-	-	-	-	-	-
23-Jun-16	19.4	0	98.550	0.044	-	-	-	-	-	-	-	-
24-Jun-16	16.9	3.4	98.545	0.040	-	-	-	-	-	-	-	-
25-Jun-16	18.1	0	98.548	0.039	-	-	-	-	-	-	-	-
26-Jun-16	18.7	0	98.609	0.061	-	-	-	-	-	-	-	-
27-Jun-16	19.9	0.6	98.578	0.045	-	-	-	-	-	-	-	-
28-Jun-16	21.4	0	98.550	0.033	-	-	-	-	-	-	-	-
29-Jun-16	21.2	0	98.530	0.026	-	-	-	-	99.452	1.132	-	-
30-Jun-16	24.3	0	98.539	0.026	-	-	-	-	99.422	0.992	-	-
01-Jul-16	23.2	0	98.539	0.024	-	-	-	-	99.388	0.848	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
02-Jul-16	21.3	0	98.548	0.023	-	-	-	-	99.351	0.707	-	-
03-Jul-16	19.0	4.2	98.550	0.022	-	-	-	-	99.300	0.541	-	-
04-Jul-16	16.8	12.4	98.570	0.023	-	-	-	-	99.329	0.616	-	-
05-Jul-16	17.1	2	98.786	0.120	-	-	-	-	99.447	1.025	-	-
06-Jul-16	15.6	0	98.714	0.061	-	-	-	-	99.460	1.065	-	-
07-Jul-16	13.8	0.2	98.686	0.045	-	-	-	-	99.458	1.043	-	-
08-Jul-16	17.7	0	98.677	0.038	-	-	-	-	99.472	1.087	-	-
09-Jul-16	18.1	0	98.656	0.030	-	-	-	-	99.468	1.056	-	-
10-Jul-16	19.1	0	98.642	0.024	-	-	-	-	99.465	1.030	-	-
11-Jul-16	20.3	0	98.635	0.021	-	-	-	-	99.448	0.948	-	-
12-Jul-16	18.3	0	98.634	0.019	-	-	-	-	99.420	0.829	-	-
13-Jul-16	17.4	0	98.625	0.016	-	-	-	-	99.377	0.671	-	-
14-Jul-16	18.2	0	98.630	0.015	-	-	-	-	99.346	0.566	-	-
15-Jul-16	19.7	0	98.628	0.014	-	-	-	-	99.304	0.443	-	-
16-Jul-16	19.8	0	98.633	0.013	-	-	-	-	99.261	0.334	-	-
17-Jul-16	17.0	0	98.632	0.012	-	-	-	-	99.201	0.214	-	-
18-Jul-16	20.7	0	98.627	0.010	-	-	-	-	99.123	0.106	-	-
19-Jul-16	22.9	3.2	98.639	0.010	-	-	-	-	99.108	0.087	-	-
20-Jul-16	19.0	1.4	98.647	0.010	-	-	-	-	99.063	0.047	-	-
21-Jul-16	14.6	0.6	98.658	0.010	-	-	-	-	99.050	0.037	-	-
22-Jul-16	14.9	0.2	98.659	0.009	-	-	-	-	99.047	0.033	-	-
23-Jul-16	18.9	0	98.669	0.009	-	-	-	-	99.062	0.040	-	-
24-Jul-16	17.3	1.6	98.678	0.009	-	-	-	-	99.079	0.049	-	-
25-Jul-16	16.2	0	98.686	0.009	-	-	-	-	99.090	0.054	-	-
26-Jul-16	20.9	0	98.693	0.009	-	-	-	-	99.106	0.064	-	-
27-Jul-16	21.1	0	98.701	0.008	-	-	-	-	99.050	0.028	-	-
28-Jul-16	21.2	0	98.709	0.008	-	-	-	-	99.044	0.025	-	-
29-Jul-16	22.9	0	98.717	0.008	-	-	-	-	99.031	0.020	-	-
30-Jul-16	18.9	0	98.724	0.008	-	-	-	-	99.021	0.016	-	-
31-Jul-16	15.9	2.6	98.735	0.008	-	-	-	-	99.012	0.012	-	-
01-Aug-16	15.9	6.8	98.746	0.008	-	-	-	-	99.027	0.016	-	-
02-Aug-16	18.4	0	98.753	0.008	-	-	-	-	99.033	0.016	-	-
03-Aug-16	16.8	0	98.755	0.007	-	-	-	-	99.007	0.007	-	-
04-Aug-16	17.3	0	98.762	0.007	-	-	-	-	98.996	0.003	-	-
05-Aug-16	18.3	0	98.763	0.006	-	-	-	-	98.980	0.000	-	-
06-Aug-16	17.8	0	98.766	0.006	-	-	-	-	98.959	0.000	-	-
07-Aug-16	15.5	0	98.768	0.005	-	-	-	-	98.948	0.000	-	-
08-Aug-16	18.5	0	98.769	0.005	-	-	-	-	98.944	0.000	-	-
09-Aug-16	14.5	6.4	98.766	0.004	-	-	-	-	98.971	0.000	-	-
10-Aug-16	19.1	0	98.769	0.004	-	-	-	-	98.963	0.000	-	-
11-Aug-16	20.5	1	98.775	0.004	-	-	-	-	98.981	0.000	-	-
12-Aug-16	18.1	0.6	98.775	0.004	-	-	-	-	99.037	0.007	-	-
13-Aug-16	18.2	0.2	98.778	0.003	-	-	-	-	99.119	0.032	-	-
14-Aug-16	19.0	0	98.783	0.003	-	-	-	-	99.145	0.046	-	-
15-Aug-16	19.9	0	98.790	0.003	-	-	-	-	99.134	0.037	-	-
16-Aug-16	21.0	0	98.786	0.003	-	-	-	-	99.132	0.034	-	-
17-Aug-16	15.7	0.4	98.799	0.003	-	-	-	-	99.163	0.051	-	-
18-Aug-16	14.0	0	98.803	0.003	-	-	-	-	99.170	0.054	-	-
19-Aug-16	13.8	0	98.804	0.002	-	-	-	-	99.167	0.049	-	-
20-Aug-16	14.3	7	98.800	0.002	-	-	-	-	99.195	0.068	-	-
21-Aug-16	14.7	0	98.812	0.002	-	-	-	-	99.220	0.088	-	-
22-Aug-16	14.3	0	98.821	0.003	-	-	-	-	99.223	0.089	-	-
23-Aug-16	15.2	0	98.836	0.003	-	-	-	-	99.219	0.087	-	-
24-Aug-16	16.3	0	98.839	0.003	-	-	-	-	99.214	0.084	-	-
25-Aug-16	14.6	0.2	98.839	0.003	-	-	-	-	99.217	0.088	-	-
26-Aug-16	16.5	0	98.839	0.003	-	-	-	-	99.210	0.083	-	-
27-Aug-16	13.7	21.6	98.831	0.003	-	-	-	-	99.208	0.082	-	-
28-Aug-16	8.7	5.2	98.828	0.003	-	-	-	-	99.238	0.116	-	-
29-Aug-16	9.7	0	98.821	0.003	-	-	-	-	99.242	0.122	-	-
30-Aug-16	11.5	0	98.822	0.003	-	-	-	-	99.242	0.123	-	-
31-Aug-16	13.3	2.8	98.824	0.003	-	-	-	-	99.241	0.124	-	-
01-Sep-16	14.6	4	98.845	0.004	-	-	-	-	99.250	0.136	-	-
02-Sep-16	14.0	1.8	98.862	0.005	-	-	-	-	99.248	0.137	-	-
03-Sep-16	9.2	38.2	98.872	0.005	-	-	-	-	99.249	0.139	-	-
04-Sep-16	9.2	0	99.039	0.021	-	-	-	-	99.327	0.259	-	-
05-Sep-16	11.4	0	98.940	0.010	-	-	-	-	99.356	0.321	-	-
06-Sep-16	12.6	0	98.935	0.009	-	-	-	-	99.398	0.420	-	-
07-Sep-16	11.6	0	98.929	0.009	-	-	-	-	99.425	0.495	-	-
08-Sep-16	9.9	1.2	98.931	0.010	-	-	-	-	99.430	0.512	-	-
09-Sep-16	9.1	0.2	98.921	0.009	-	-	-	-	99.434	0.529	-	-
10-Sep-16	11.4	1	98.917	0.009	-	-	-	-	99.434	0.532	-	-
11-Sep-16	7.1	2.6	98.922	0.010	-	-	-	-	99.431	0.527	-	-
12-Sep-16	8.1	0	98.941	0.011	-	-	-	-	99.430	0.530	-	-
13-Sep-16	14.2	0	98.931	0.011	-	-	-	-	99.430	0.533	-	-
14-Sep-16	12.6	0	98.922	0.010	-	-	-	-	99.431	0.542	-	-
15-Sep-16	10.6	0	98.926	0.011	-	-	-	-	99.429	0.539	-	-
16-Sep-16	15.7	0	98.938	0.012	-	-	-	-	99.419	0.515	-	-
17-Sep-16	14.4	0.4	98.943	0.013	-	-	-	-	99.409	0.493	-	-
18-Sep-16	9.4	3.4	98.958	0.015	-	-	-	-	99.404	0.483	-	-
19-Sep-16	8.6	1	98.971	0.018	-	-	-	-	99.416	0.521	-	-
20-Sep-16	8.1	0	98.997	0.022	-	-	-	-	99.423	0.544	-	-
21-Sep-16	9.2	0	99.001	0.024	-	-	-	-	99.417	0.530	-	-
22-Sep-16	13.5	0	98.998	0.024	-	-	-	-	99.410	0.517	-	-
23-Sep-16	11.7	0	98.988	0.022	-	-	-	-	99.412	0.525	-	-
24-Sep-16	11.6	0	99.004	0.026	-	-	-	-	99.409	0.523	-	-
25-Sep-16	9.4	0	99.015	0.029	-	-	-	-	99.398	0.496	-	-
26-Sep-16	13.4	0	99.011	0.029	-	-	-	-	99.385	0.465	-	-
27-Sep-16	13.6	0.4	99.007	0.029	-	-	-	-	99.377	0.449	-	-
28-Sep-16	8.9	0	99.002	0.028	-	-	-	-	99.365	0.422	-	-
29-Sep-16	9.2	0	98.998	0.028	-	-	-	-	99.354	0.400	-	-
30-Sep-16	5.1	0	99.004	0.030	-	-	-	-	99.347	0.386	-	-
01-Oct-16	5.5	6.2	99.003	0.031	-	-	-	-	99.332	0.355	-	-
02-Oct-16	4.5	3.4	99.008	0.033	-	-	-	-	99.356	0.416	-	-
03-Oct-16	3.6	0	99.026	0.039	-	-	-	-	99.405	0.549	-	-
04-Oct-16	3.3	0	99.012	0.036	-	-	-	-	99.415	0.584	-	-
05-Oct-16	-0.2	0	99.004	0.034	-	-	-	-	99.423	0.611	-	-
06-Oct-16	-0.6	0	99.004	0.035	-	-	-	-	99.423	0.615	-	-
07-Oct-16	0.3	0	99.002	0.035	-	-	-	-	99.411	0.585	-	-
08-Oct-16	0.9	0	99.001	0.036	-	-	-	-	99.402	0.562	-	-
09-Oct-16	0.3	2	98.998	0.036	-	-	-	-	99.393	0.542	-	-
10-Oct-16	1.0	0	98.999	0.037	-	-	-	-	99.403	0.574	-	-
11-Oct-16	0.4	0	98.998	0.038	-	-	-	-	99.400	0.572	-	-
12-Oct-16	-1.4	0	98.997	0.039	-	-	-	-	99.392	0.552	-	-
13-Oct-16	-1.6	0	98.993	0.039	-	-	-	-	99.387	0.541	-	-
14-Oct-16	-2.6	0.2	98.989	0.038	-	-	-	-	99.382	0.533	-	-
15-Oct-16	-2.3	0.6	98.985	0.038	-	-	-	-	99.373	0.511	-	-
16-Oct-16	-1.1	0	98.984	0.038	-	-	-	-	99.367	0.501	-	-
17-Oct-16	-0.6	0	98.979	0.038	-	-	-	-	99.368	0.507	-	-
18-Oct-16	-0.6	0	98.983	0.040	-	-	-	-	99.372	0.521	-	-
19-Oct-16	1.3	8.2	98.976	0.039	-	-	-	-	99.376	0.538	-	-
20-Oct-16	3.5	0	98.975	0.040	-	-	-	-	99.379	0.549	-	-
21-Oct-16	2.4	0	98.976	0.041	-	-	-	-	99.380	0.558	-	-
22-Oct-16	1.1	1.2	98.980	0.044	-	-	-	-	99.384	0.573	-	-
23-Oct-16	1.6	0.2	98.980	0.045	-	-	-	-	99.383	0.574	-	-
24-Oct-16	1.3	0	98.982	0.046	-	-	-	-	99.382	0.577	-	-
25-Oct-16	1.7	0.2	98.980	0.047	-	-	-	-	99.380	0.574	-	-
26-Oct-16	1.5	0.2	98.976	0.047	-	-	-	-	99.382	0.584	-	-
27-Oct-16	-	-	98.979	0.048	-	-	-	-	99.385	0.593	-	-
28-Oct-16	-	-	98.982	0.050	-	-	-	-	99.387	0.602	-	-
29-Oct-16	-	-	98.982	0.050	-	-	-	-	99.389	0.611	-	-
30-Oct-16	-	-	98.983	0.051	-	-	-	-	99.392	0.621	-	-
31-Oct-16	-	-	98.985	0.052	-	-	-	-	99.394	0.630	-	-
01-Nov-16	-	-	98.985	0.052	98.315	0.059	-	-	99.396	0.639	-	-
02-Nov-16	-	-	98.980	0.050	98.297	0.054	-	-	99.374	0.575	-	-
03-Nov-16	-	-	98.979	0.050	98.289	0.051	-	-	99.355	0.523	-	-
04-Nov-16	-	-	98.984	0.052	98.301	0.055	-	-	99.363	0.548	-	-
05-Nov-16	-	-	98.988	0.054	98.306	0.057	-	-	99.373	0.579	-	-
06-Nov-16	-	-	98.989	0.055	98.309	0.058	-	-	99.384	0.614	-	-
07-Nov-16	-	-	98.990	0.056	98.306	0.057	-	-	99.385	0.620	-	-
08-Nov-16	-	-	98.987	0.054	98.300	0.055	-	-	99.380	0.607	-	-
09-Nov-16	-	-	98.987	0.055	98.299	0.054	-	-	99.386	0.628	-	-
10-Nov-16	-	-	98.989	0.056	98.299	0.054	-	-	99.392	0.649	-	-
11-Nov-16	-	-	98.988	0.056	98.295	0.053	-	-	99.390	0.645	-	-
12-Nov-16	-	-	98.987	0.055	98.296	0.053	-	-	99.396	0.667	-	-
13-Nov-16	-	-	98.987	0.056	98.291	0.052	-	-	99.394	0.663	-	-
14-Nov-16	-	-	98.989	0.057	98.294	0.053	-	-	99.385	0.637	-	-
15-Nov-16	-	-	98.989	0.057	98.308	0.057	-	-	99.394	0.668	-	-
16-Nov-16	-	-	98.987	0.056	98.300	0.055	-	-	-	-	-	-
17-Nov-16	-	-	98.985	0.056	98.294	0.053	-	-	99.359	0.566	-	-
18-Nov-16	-	-	98.981	0.054	98.281	0.049	-	-	-	-	-	-
19-Nov-16	-	-	98.981	0.055	98.269	0.045	-	-	-	-	-	-
20-Nov-16	-	-	98.977	0.053	98.261	0.042	-	-	99.300	0.415	-	-
21-Nov-16	-	-	98.981	0.055	98.260	0.042	-	-	99.284	0.378	-	-
22-Nov-16	-	-	98.978	0.054	98.261	0.042	-	-	99.278	0.366	-	-
23-Nov-16	-	-	98.976	0.053	98.260	0.042	-	-	99.270	0.350	-	-
24-Nov-16	-	-	98.974	0.053	98.261	0.042	-	-	99.267	0.345	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
25-Nov-16	-	-	98.976	0.054	98.264	0.043	-	-	99.265	0.343	-	-
26-Nov-16	-	-	98.975	0.054	98.265	0.043	-	-	99.262	0.338	-	-
27-Nov-16	-	-	98.975	0.054	98.267	0.044	-	-	99.261	0.337	-	-
28-Nov-16	-	-	98.976	0.055	98.273	0.046	-	-	99.263	0.344	-	-
29-Nov-16	-	-	98.975	0.054	98.267	0.044	-	-	99.257	0.332	-	-
30-Nov-16	-	-	98.974	0.054	98.267	0.044	-	-	99.253	0.325	-	-
01-Dec-16	-	-	98.973	0.054	98.271	0.045	-	-	99.253	0.327	-	-
02-Dec-16	-	-	98.972	0.054	98.271	0.045	-	-	99.252	0.327	-	-
03-Dec-16	-	-	98.971	0.054	98.268	0.044	-	-	99.250	0.324	-	-
04-Dec-16	-	-	98.971	0.054	98.269	0.045	-	-	99.250	0.326	-	-
05-Dec-16	-	-	98.971	0.054	98.269	0.045	-	-	-	-	-	-
06-Dec-16	-	-	98.970	0.054	98.267	0.044	-	-	-	-	-	-
07-Dec-16	-	-	98.966	0.052	98.265	0.043	-	-	-	-	-	-
08-Dec-16	-	-	-	-	98.266	0.044	-	-	-	-	-	-
09-Dec-16	-	-	-	-	98.246	0.037	-	-	-	-	-	-
10-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
11-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
12-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
13-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
14-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
15-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
16-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
17-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
18-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
19-Dec-16	-	-	-	-	-	-	-	-	-	-	-	-
20-Dec-16	-	-	-	-	-	-	-	-	99.102	0.112	-	-
21-Dec-16	-	-	-	-	-	-	-	-	99.097	0.108	-	-
22-Dec-16	-	-	-	-	-	-	-	-	99.095	0.106	-	-
23-Dec-16	-	-	-	-	-	-	-	-	99.092	0.104	-	-
24-Dec-16	-	-	-	-	-	-	-	-	99.089	0.102	-	-
25-Dec-16	-	-	-	-	-	-	-	-	99.086	0.099	-	-
26-Dec-16	-	-	-	-	-	-	-	-	99.083	0.097	-	-
27-Dec-16	-	-	-	-	-	-	-	-	99.080	0.095	-	-
28-Dec-16	-	-	-	-	-	-	-	-	99.081	0.097	-	-
29-Dec-16	-	-	-	-	-	-	-	-	99.079	0.096	-	-
30-Dec-16	-	-	-	-	-	-	-	-	99.076	0.093	-	-
31-Dec-16	-	-	-	-	-	-	-	-	99.082	0.100	-	-
01-Jan-17	-19.8	-	-	-	-	-	-	-	99.076	0.095	-	-
02-Jan-17	-19.1	-	-	-	-	-	-	-	99.071	0.090	-	-
03-Jan-17	-18.0	-	-	-	-	-	-	-	99.066	0.087	-	-
04-Jan-17	-13.5	-	-	-	-	-	-	-	99.061	0.082	-	-
05-Jan-17	-14.9	-	-	-	-	-	-	-	99.058	0.080	-	-
06-Jan-17	-22.9	-	-	-	-	-	-	-	99.053	0.077	-	-
07-Jan-17	-23.7	-	-	-	-	-	-	-	99.047	0.072	-	-
08-Jan-17	-25.7	-	-	-	-	-	-	-	99.041	0.067	-	-
09-Jan-17	-23.1	-	-	-	-	-	-	-	99.034	0.063	-	-
10-Jan-17	-31.9	-	-	-	-	-	-	-	99.028	0.058	-	-
11-Jan-17	-25.0	-	-	-	-	-	-	-	99.022	0.054	-	-
12-Jan-17	-27.3	-	-	-	-	-	-	-	99.015	0.050	-	-
13-Jan-17	-15.5	-	-	-	-	-	-	-	99.009	0.046	-	-
14-Jan-17	-4.3	-	-	-	-	-	-	-	99.001	0.042	-	-
15-Jan-17	0.6	-	-	-	-	-	-	-	98.997	0.040	-	-
16-Jan-17	2.7	-	-	-	-	-	-	-	98.993	0.038	-	-
17-Jan-17	3.6	-	-	-	-	-	-	-	99.005	0.046	-	-
18-Jan-17	-0.7	-	-	-	-	-	-	-	98.988	0.036	-	-
19-Jan-17	-6.0	-	-	-	-	-	-	-	98.989	0.037	-	-
20-Jan-17	-3.2	-	-	-	-	-	-	-	98.989	0.037	-	-
21-Jan-17	-8.5	-	-	-	-	-	-	-	98.988	0.037	-	-
22-Jan-17	-16.7	-	-	-	-	-	-	-	98.984	0.035	-	-
23-Jan-17	-16.5	-	-	-	-	-	-	-	98.984	0.035	-	-
24-Jan-17	-10.4	-	-	-	-	-	-	-	98.983	0.036	-	-
25-Jan-17	-5.8	-	-	-	-	-	-	-	98.984	0.037	-	-
26-Jan-17	-3.2	-	-	-	-	-	-	-	98.985	0.038	-	-
27-Jan-17	-0.5	-	-	-	-	-	-	-	98.984	0.037	-	-
28-Jan-17	0.7	-	-	-	-	-	-	-	98.984	0.038	-	-
29-Jan-17	2.1	-	-	-	-	-	-	-	98.991	0.043	-	-
30-Jan-17	-7.7	-	-	-	-	-	-	-	98.992	0.044	-	-
31-Jan-17	-15.6	-	-	-	-	-	-	-	98.987	0.041	-	-
01-Feb-17	-17.7	-	-	-	-	-	-	-	98.986	0.041	-	-
02-Feb-17	-15.6	-	-	-	-	-	-	-	98.986	0.041	-	-
03-Feb-17	-16.3	-	-	-	-	-	-	-	98.984	0.041	-	-
04-Feb-17	-24.0	-	-	-	-	-	-	-	98.984	0.041	-	-
05-Feb-17	-26.4	-	-	-	-	-	-	-	98.979	0.039	-	-
06-Feb-17	-28.2	-	-	-	-	-	-	-	98.974	0.036	-	-
07-Feb-17	-22.6	-	-	-	-	-	-	-	98.969	0.034	-	-
08-Feb-17	-16.0	-	-	-	-	-	-	-	98.965	0.032	-	-
09-Feb-17	-15.5	-	-	-	-	-	-	-	98.958	0.029	-	-
10-Feb-17	-15.5	-	-	-	-	-	-	-	98.959	0.030	-	-
11-Feb-17	-6.2	-	-	-	-	-	-	-	98.961	0.031	-	-
12-Feb-17	2.3	-	-	-	-	-	-	-	98.962	0.032	-	-
13-Feb-17	-0.3	-	-	-	-	-	-	-	98.940	0.025	-	-
14-Feb-17	4.5	-	-	-	-	-	-	-	98.944	0.026	-	-
15-Feb-17	9.1	-	-	-	-	-	-	-	98.956	0.030	-	-
16-Feb-17	6.4	-	-	-	-	-	-	-	98.962	0.034	-	-
17-Feb-17	-1.1	-	-	-	-	-	-	-	98.966	0.037	-	-
18-Feb-17	-3.6	-	-	-	-	-	-	-	98.968	0.038	-	-
19-Feb-17	-2.6	-	-	-	-	-	-	-	98.973	0.042	-	-
20-Feb-17	-3.0	-	-	-	-	-	-	-	98.978	0.046	-	-
21-Feb-17	-7.8	-	-	-	-	-	-	-	98.978	0.046	-	-
22-Feb-17	-14.7	-	-	-	-	-	-	-	98.974	0.044	-	-
23-Feb-17	-14.5	-	-	-	-	-	-	-	98.973	0.044	-	-
24-Feb-17	-16.5	-	-	-	-	-	-	-	98.974	0.045	-	-
25-Feb-17	-12.4	-	-	-	-	-	-	-	98.973	0.045	-	-
26-Feb-17	-19.6	-	-	-	-	-	-	-	98.967	0.042	-	-
27-Feb-17	-19.4	-	-	-	-	-	-	-	98.969	0.043	-	-
28-Feb-17	-21.3	-	-	-	-	-	-	-	98.970	0.045	-	-
01-Mar-17	-25.3	-	-	-	-	-	-	-	98.965	0.042	-	-
02-Mar-17	-16.6	-	-	-	-	-	-	-	98.961	0.040	-	-
03-Mar-17	-6.8	-	-	-	-	-	-	-	98.964	0.042	-	-
04-Mar-17	-19.4	-	-	-	-	-	-	-	98.963	0.042	-	-
05-Mar-17	-17.3	-	-	-	-	-	-	-	98.962	0.042	-	-
06-Mar-17	-18.4	-	-	-	-	-	-	-	98.959	0.041	-	-
07-Mar-17	-23.4	-	-	-	-	-	-	-	98.953	0.038	-	-
08-Mar-17	-25.5	-	-	-	-	-	-	-	98.960	0.042	-	-
09-Mar-17	-26.8	-	-	-	-	-	-	-	98.966	0.047	-	-
10-Mar-17	-24.8	-	-	-	-	-	-	-	98.969	0.049	-	-
11-Mar-17	-19.5	-	-	-	-	-	-	-	98.961	0.044	-	-
12-Mar-17	-14.4	-	-	-	-	-	-	-	98.953	0.040	-	-
13-Mar-17	-8.7	-	-	-	-	-	-	-	98.960	0.045	-	-
14-Mar-17	1.7	-	-	-	-	-	-	-	98.943	0.035	-	-
15-Mar-17	4.5	-	-	-	-	-	-	-	98.950	0.039	-	-
16-Mar-17	-5.5	-	-	-	-	-	-	-	98.944	0.036	-	-
17-Mar-17	-5.7	-	-	-	-	-	-	-	98.937	0.033	-	-
18-Mar-17	-2.4	-	-	-	-	-	-	-	98.942	0.036	-	-
19-Mar-17	-6.9	-	-	-	-	-	-	-	98.948	0.040	-	-
20-Mar-17	-14.6	-	-	-	-	-	-	-	98.908	0.024	-	-
21-Mar-17	-3.5	-	-	-	-	-	-	-	98.902	0.022	-	-
22-Mar-17	-0.3	-	-	-	-	-	-	-	98.908	0.024	-	-
23-Mar-17	-1.8	-	-	-	-	-	-	-	98.854	0.008	-	-
24-Mar-17	3.1	-	-	-	-	-	-	-	98.851	0.007	-	-
25-Mar-17	0.8	-	-	-	-	-	-	-	98.856	0.009	-	-
26-Mar-17	0.4	-	-	-	-	-	-	-	98.858	0.010	-	-
27-Mar-17	3.6	-	-	-	-	-	-	-	98.868	0.013	-	-
28-Mar-17	5.0	-	-	-	-	-	-	-	98.867	0.013	-	-
29-Mar-17	5.9	-	-	-	-	-	-	-	98.915	0.028	-	-
30-Mar-17	1.3	-	-	-	-	-	-	-	98.984	0.074	-	-
31-Mar-17	7.1	-	-	-	-	-	-	-	98.989	0.079	-	-
01-Apr-17	7.8	-	-	-	98.254	0.040	-	-	99.035	0.129	-	-
02-Apr-17	6.5	-	-	-	98.369	0.068	-	-	99.072	0.179	-	-
03-Apr-17	3.2	-	-	-	98.372	0.078	-	-	99.114	0.246	-	-
04-Apr-17	3.7	-	-	-	98.400	0.094	-	-	99.152	0.321	-	-
05-Apr-17	6.3	-	-	-	98.420	0.096	-	-	99.190	0.410	-	-
06-Apr-17	10.5	-	-	-	98.457	0.102	-	-	99.222	0.493	-	-
07-Apr-17	6.9	-	98.976	0.096	98.497	0.113	-	-	99.209	0.461	-	-
08-Apr-17	-3.2	-	98.977	0.094	98.493	0.112	-	-	99.207	0.457	-	-
09-Apr-17	-0.1	-	98.962	0.081	98.433	0.096	-	-	99.196	0.428	-	-
10-Apr-17	5.5	-	98.959	0.077	98.362	0.075	-	-	99.195	0.428	-	-
11-Apr-17	0.6	-	98.945	0.067	98.330	0.064	-	-	99.188	0.411	-	-
12-Apr-17	-1.4	-	98.928	0.057	98.308	0.057	-	-	99.169	0.367	-	-
13-Apr-17	2.0	-	98.939	0.061	98.289	0.051	-	-	99.164	0.357	-	-
14-Apr-17	1.8	-	98.935	0.057	98.286	0.050	-	-	99.157	0.340	-	-
15-Apr-17	0.4	-	98.933	0.055	98.253	0.040	-	-	99.141	0.307	-	-
16-Apr-17	3.5	-	98.926	0.050	98.249	0.038	-	-	99.130	0.287	-	-
17-Apr-17	-4.0	-	98.927	0.049	98.243	0.036	-	-	99.126	0.278	-	-
18-Apr-17	-6.1	-	98.922	0.046	98.240	0.035	-	-	99.110	0.250	-	-
19-Apr-17	-1.6	-	98.924	0.046	98.234	0.033	-	-	99.093	0.221	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
20-Apr-17	-2.3	-	98.921	0.043	98.228	0.031	-	-	99.076	0.195	-	-
21-Apr-17	-5.2	-	98.920	0.042	98.221	0.029	-	-	99.065	0.179	-	-
22-Apr-17	-5.5	-	98.920	0.041	98.217	0.028	-	-	99.054	0.164	-	-
23-Apr-17	-3.4	-	98.918	0.039	98.208	0.025	-	-	99.039	0.145	-	-
24-Apr-17	1.3	0	98.914	0.037	98.202	0.023	-	-	99.035	0.140	-	-
25-Apr-17	3.2	0	98.915	0.036	98.196	0.021	-	-	99.031	0.135	-	-
26-Apr-17	3.5	0	98.921	0.037	98.179	0.016	-	-	99.027	0.131	-	-
27-Apr-17	6.3	0	98.930	0.039	98.199	0.022	-	-	99.027	0.131	-	-
28-Apr-17	5.8	0	98.918	0.034	98.189	0.019	-	-	99.028	0.133	-	-
29-Apr-17	10.4	0	98.918	0.033	98.204	0.024	-	-	99.023	0.127	-	-
30-Apr-17	8.7	0	98.931	0.036	98.201	0.023	-	-	99.022	0.126	-	-
01-May-17	7.3	0	98.922	0.033	98.202	0.023	-	-	99.010	0.113	-	-
02-May-17	4.7	2.2	98.923	0.032	98.196	0.021	-	-	98.986	0.088	-	-
03-May-17	10.8	0	98.922	0.031	98.202	0.023	-	-	99.031	0.143	-	-
04-May-17	12.8	0	98.928	0.032	98.163	0.011	-	-	99.043	0.154	-	-
05-May-17	16.4	0.2	98.925	0.030	98.166	0.012	-	-	99.051	0.165	-	-
06-May-17	17.1	0.2	98.921	0.028	98.179	0.016	-	-	99.071	0.195	-	-
07-May-17	10.3	4.2	98.931	0.030	98.181	0.016	-	-	99.099	0.240	-	-
08-May-17	10.6	0	98.951	0.034	98.207	0.025	-	-	99.152	0.346	-	-
09-May-17	14.2	0	98.932	0.029	98.197	0.022	-	-	99.162	0.369	-	-
10-May-17	11.7	0	98.923	0.026	98.190	0.019	-	-	99.173	0.395	-	-
11-May-17	10.8	0	98.932	0.027	98.171	0.013	-	-	99.191	0.440	-	-
12-May-17	10.2	0	98.936	0.027	98.169	0.013	-	-	99.186	0.429	-	-
13-May-17	6.7	8.4	98.942	0.028	98.166	0.012	-	-	99.179	0.412	-	-
14-May-17	3.9	9.6	98.954	0.030	98.207	0.025	-	-	99.244	0.588	-	-
15-May-17	5.1	0.2	98.975	0.034	98.295	0.053	-	-	99.323	0.850	-	-
16-May-17	7.7	0	98.971	0.032	98.284	0.050	-	-	99.344	0.932	-	-
17-May-17	9.5	0	98.965	0.030	98.260	0.042	-	-	99.387	1.108	-	-
18-May-17	12.4	1	98.960	0.028	98.247	0.038	-	-	99.401	1.169	-	-
19-May-17	14.5	0	98.963	0.028	98.224	0.030	-	-	99.419	1.253	-	-
20-May-17	14.2	0.6	98.962	0.027	98.226	0.031	-	-	99.386	1.103	-	-
21-May-17	13.5	0.2	98.967	0.027	98.214	0.027	-	-	99.386	1.103	-	-
22-May-17	18.9	0	98.955	0.024	98.211	0.026	-	-	99.361	0.999	-	-
23-May-17	18.7	0	98.953	0.023	98.205	0.024	-	-	99.347	0.943	-	-
24-May-17	14.7	0	98.953	0.023	98.211	0.026	-	-	99.320	0.841	-	-
25-May-17	12.7	0	98.952	0.022	98.198	0.022	-	-	99.293	0.746	-	-
26-May-17	10.2	0	98.952	0.021	98.180	0.016	-	-	99.260	0.638	-	-
27-May-17	12.7	0	98.958	0.022	98.170	0.011	-	-	99.235	0.563	-	-
28-May-17	12.1	0	98.960	0.022	98.161	0.010	-	-	99.206	0.483	-	-
29-May-17	13.5	0	98.966	0.022	-	-	-	-	99.181	0.419	-	-
30-May-17	19.4	0	98.969	0.022	-	-	-	-	99.141	0.327	-	-
31-May-17	24.5	0	98.961	0.020	-	-	-	-	99.141	0.327	-	-
01-Jun-17	19.0	1	98.968	0.021	-	-	-	-	99.100	0.247	-	-
02-Jun-17	17.7	13.2	98.969	0.020	-	-	-	-	99.080	0.213	-	-
03-Jun-17	16.7	0.8	98.984	0.022	-	-	-	-	99.077	0.208	-	-
04-Jun-17	17.1	0.2	98.991	0.023	98.176	0.015	-	-	99.158	0.364	-	-
05-Jun-17	12.5	15	98.989	0.022	98.173	0.014	-	-	99.138	0.321	-	-
06-Jun-17	16.6	0.2	99.022	0.028	98.275	0.047	-	-	99.251	0.611	-	-
07-Jun-17	19.4	0	99.011	0.025	98.249	0.038	-	-	99.303	0.780	-	-
08-Jun-17	20.2	0	99.008	0.024	98.236	0.034	-	-	99.379	1.074	-	-
09-Jun-17	17.0	0	99.000	0.022	98.210	0.026	-	-	99.399	1.160	-	-
10-Jun-17	10.7	0.4	99.000	0.021	98.190	0.019	-	-	99.393	1.134	-	-
11-Jun-17	9.4	0.2	98.996	0.020	98.181	0.016	-	-	99.396	1.147	-	-
12-Jun-17	12.5	3.6	98.996	0.019	98.175	0.014	-	-	99.376	1.061	-	-
13-Jun-17	17.5	0	99.002	0.020	98.171	0.013	-	-	99.367	1.024	-	-
14-Jun-17	12.7	1.6	99.000	0.019	98.175	0.010	-	-	99.347	0.943	-	-
15-Jun-17	14.3	1.6	99.002	0.019	97.176	0.012	-	-	99.323	0.852	-	-
16-Jun-17	15.6	1.8	99.008	0.019	98.178	0.015	-	-	99.336	0.901	-	-
17-Jun-17	15.0	2.6	98.998	0.017	98.215	0.027	-	-	99.314	0.820	-	-
18-Jun-17	14.7	0	98.998	0.017	98.250	0.039	-	-	99.293	0.746	-	-
19-Jun-17	16.6	0.4	98.996	0.016	98.238	0.035	-	-	99.268	0.663	-	-
20-Jun-17	15.1	1.2	98.993	0.015	98.215	0.027	-	-	99.241	0.581	-	-
21-Jun-17	11.7	17.8	98.993	0.015	98.205	0.024	-	-	99.231	0.552	-	-
22-Jun-17	10.6	0	99.012	0.017	98.264	0.043	-	-	99.314	0.820	-	-
23-Jun-17	12.6	0	99.010	0.017	98.264	0.043	-	-	99.310	0.805	-	-
24-Jun-17	15.2	0	99.004	0.015	98.249	0.038	-	-	99.311	0.809	-	-
25-Jun-17	17.4	0	99.003	0.015	98.224	0.030	-	-	99.317	0.830	-	-
26-Jun-17	22.3	0	98.998	0.014	98.197	0.022	-	-	99.299	0.767	-	-
27-Jun-17	15.4	3.4	98.993	0.013	98.181	0.016	-	-	99.260	0.638	-	-
28-Jun-17	15.4	1.6	98.995	0.013	98.204	0.024	-	-	99.257	0.629	-	-
29-Jun-17	16.6	0	98.996	0.013	98.196	0.021	-	-	99.244	0.590	-	-
30-Jun-17	17.4	0	98.992	0.012	98.188	0.019	-	-	99.211	0.496	-	-
01-Jul-17	18.7	0	98.991	0.012	98.172	0.014	-	-	99.185	0.429	-	-
02-Jul-17	21.5	0.4	98.992	0.011	98.160	0.010	-	-	99.169	0.390	-	-
03-Jul-17	19.8	1.2	98.990	0.011	98.204	0.024	-	-	99.204	0.478	-	-
04-Jul-17	18.3	0	98.987	0.010	98.184	0.017	-	-	99.180	0.416	-	-
05-Jul-17	16.8	0	98.986	0.010	98.174	0.014	-	-	99.144	0.333	-	-
06-Jul-17	17.9	0	98.983	0.010	-	-	-	-	99.118	0.280	-	-
07-Jul-17	20.0	0	98.981	0.009	-	-	-	-	99.078	0.210	-	-
08-Jul-17	20.6	0	98.975	0.008	-	-	-	-	99.040	0.155	-	-
09-Jul-17	21.2	0	98.975	0.008	-	-	-	-	98.995	0.101	-	-
10-Jul-17	19.0	11.6	98.977	0.008	-	-	-	-	98.956	0.065	-	-
11-Jul-17	18.8	0	98.982	0.008	98.191	0.020	-	-	98.951	0.060	-	-
12-Jul-17	19.1	0	98.981	0.008	98.169	0.013	-	-	98.930	0.045	-	-
13-Jul-17	21.1	0	98.980	0.008	-	-	-	-	98.911	0.034	-	-
14-Jul-17	17.8	1.2	98.979	0.007	-	-	-	-	98.898	0.028	-	-
15-Jul-17	22.2	0	98.982	0.007	-	-	-	-	98.907	0.032	-	-
16-Jul-17	17.3	3.6	98.984	0.007	-	-	-	-	98.911	0.034	-	-
17-Jul-17	12.3	7.4	98.998	0.008	-	-	-	-	98.981	0.087	-	-
18-Jul-17	11.8	0	99.002	0.008	-	-	-	-	99.046	0.163	-	-
19-Jul-17	15.7	0.6	99.000	0.008	-	-	-	-	99.053	0.172	-	-
20-Jul-17	16.7	0	99.005	0.008	-	-	-	-	99.063	0.187	-	-
21-Jul-17	19.3	2.8	99.007	0.008	-	-	-	-	99.071	0.199	-	-
22-Jul-17	22.0	0	99.016	0.008	-	-	-	-	99.077	0.208	-	-
23-Jul-17	21.0	0	99.019	0.008	-	-	-	-	99.074	0.204	-	-
24-Jul-17	16.7	0	98.986	0.006	-	-	-	-	99.085	0.221	-	-
25-Jul-17	18.5	0	98.988	0.006	-	-	-	-	99.119	0.282	-	-
26-Jul-17	24.1	0.2	98.988	0.006	-	-	-	-	99.093	0.234	-	-
27-Jul-17	23.7	0.4	98.980	0.005	-	-	-	-	99.096	0.240	-	-
28-Jul-17	18.5	1.4	98.969	0.005	-	-	-	-	99.099	0.245	-	-
29-Jul-17	16.8	1	98.968	0.005	-	-	-	-	99.106	0.257	-	-
30-Jul-17	17.7	1	98.968	0.005	-	-	-	-	99.114	0.272	-	-
31-Jul-17	15.7	0.4	98.976	0.005	-	-	-	-	99.126	0.296	-	-
01-Aug-17	15.9	0	98.982	0.005	-	-	-	-	99.126	0.296	-	-
02-Aug-17	16.5	0	98.952	0.004	-	-	-	-	99.133	0.310	-	-
03-Aug-17	20.1	0	98.954	0.004	-	-	-	-	99.142	0.329	-	-
04-Aug-17	17.1	0.2	98.954	0.004	-	-	-	-	99.140	0.325	-	-
05-Aug-17	18.8	0	98.954	0.003	-	-	-	-	99.149	0.344	-	-
06-Aug-17	13.2	5.4	98.959	0.003	-	-	-	-	99.146	0.338	-	-
07-Aug-17	12.7	0	98.980	0.004	-	-	-	-	99.174	0.402	-	-
08-Aug-17	17.0	0	98.985	0.004	-	-	-	-	99.181	0.419	-	-
09-Aug-17	21.2	0	98.984	0.004	-	-	-	-	99.182	0.421	-	-
10-Aug-17	21.0	2.8	98.983	0.004	-	-	-	-	99.174	0.402	-	-
11-Aug-17	20.4	0.2	98.983	0.004	-	-	-	-	99.178	0.411	-	-
12-Aug-17	23.1	0	98.976	0.003	-	-	-	-	99.186	0.431	-	-
13-Aug-17	24.1	0	98.974	0.003	-	-	-	-	99.198	0.462	-	-
14-Aug-17	20.1	0.2	98.967	0.003	-	-	-	-	99.224	0.533	-	-
15-Aug-17	15.7	6.4	98.965	0.003	-	-	-	-	99.239	0.575	-	-
16-Aug-17	17.3	0	98.974	0.003	-	-	-	-	99.248	0.601	-	-
17-Aug-17	18.3	0	98.937	0.002	-	-	-	-	99.250	0.608	-	-
18-Aug-17	18.1	0.2	98.937	0.002	-	-	-	-	99.250	0.608	-	-
19-Aug-17	12.4	5	98.937	0.002	-	-	-	-	99.220	0.520	-	-
20-Aug-17	14.8	0	98.944	0.002	-	-	-	-	99.219	0.519	-	-
21-Aug-17	14.5	0	98.941	0.002	-	-	-	-	99.199	0.464	-	-
22-Aug-17	13.6	0	98.938	0.002	-	-	-	-	99.202	0.472	-	-
23-Aug-17	19.2	0	98.935	0.002	-	-	-	-	99.204	0.478	-	-
24-Aug-17	18.9	1.6	98.929	0.002	-	-	-	-	99.189	0.438	-	-
25-Aug-17	12.4	8.2	98.927	0.002	-	-	-	-	99.195	0.454	-	-
26-Aug-17	17.3	0	98.940	0.002	-	-	-	-	99.195	0.453	-	-
27-Aug-17	18.1	0	98.935	0.002	-	-	-	-	99.191	0.444	-	-
28-Aug-17	14.3	0	98.928	0.002	-	-	-	-	99.196	0.457	-	-
29-Aug-17	10.2	0	98.917	0.001	-	-	96.865	6.656	99.191	0.443	-	-
30-Aug-17	19.7	0	98.908	0.001	-	-	96.860	6.495	99.175	0.404	-	-
31-Aug-17	18.6	0	98.900	0.001	-	-	96.855	6.299	99.192	0.439	-	-
01-Sep-17	16.5	0	98.891	0.001	98.074	0.064	96.847	6.001	99.192	0.422	-	-
02-Sep-17	15.6	0	98.878	0.001	98.076	0.065	96.835	5.606	99.189	0.398	-	-
03-Sep-17	14.1	0.6	98.868	0.001	98.065	0.061	96.834	5.559	99.188	0.380	-	-
04-Sep-17	11.0	0	98.857	0.001	98.071	0.063	96.826	5.312	99.187	0.362	-	-
05-Sep-17	16.9	0	98.847	0.001	98.069	0.062	96.821	5.134	99.186	0.345	-	-
06-Sep-17	17.2	0	98.835	0.001	98.065	0.061	96.815	4.960	99.186	0.330	-	-
07-Sep-17	23.9	0	98.824	0.001	98.037	0.052	96.815	4.948	99.186	0.316	-	-
08-Sep-17	18.0	0.2	98.811	0.001	98.058	0.059	96.810	4.777	99.184	0.298	-	-
09-Sep-17	12.8	2.2	98.797	0.001	98.062	0.060	96.807	4.702	99.187	0.291	-	-
10-Sep-17	13.0	0.6	98.790	0.001	98.066	0.061	96.805	4.628	99.193	0.289	-	-
11-Sep-17	11.7	3.6	98.783	0.001	98.071	0.063	96.807	4.709	99.191	0.272	-	-
12-Sep-17	9.2	0.2	98.784	0.001	98.070	0.063	96.808	4.729	99.198	0.273	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
13-Sep-17	6.7	0.4	98.780	0.001	98.082	0.067	96.814	4.938	99.198	0.260	-	-
14-Sep-17	5.4	0	98.774	0.001	98.062	0.060	96.810	4.799	99.200	0.252	-	-
15-Sep-17	5.9	0	98.766	0.001	98.071	0.063	96.815	4.946	99.200	0.240	-	-
16-Sep-17	10.4	0	98.758	0.001	98.079	0.066	96.816	4.998	99.201	0.230	-	-
17-Sep-17	10.7	0	98.749	0.001	98.088	0.068	96.815	4.954	99.202	0.221	-	-
18-Sep-17	9.5	0	98.738	0.001	98.070	0.063	96.814	4.941	99.203	0.211	-	-
19-Sep-17	7.7	1.2	98.728	0.001	98.067	0.062	96.814	4.929	99.202	0.199	-	-
20-Sep-17	6.3	17.4	98.724	0.001	98.077	0.065	96.815	4.981	99.204	0.192	-	-
21-Sep-17	4.5	4.2	98.772	0.001	98.118	0.078	96.843	5.908	99.228	0.219	-	-
22-Sep-17	4.5	0.4	98.792	0.001	98.137	0.084	96.861	6.576	99.226	0.205	-	-
23-Sep-17	5.7	0	98.791	0.001	98.137	0.084	96.889	7.630	99.224	0.192	-	-
24-Sep-17	9.4	0	98.786	0.001	98.122	0.079	96.903	8.178	99.223	0.180	-	-
25-Sep-17	13.7	0	98.781	0.001	98.114	0.077	96.921	8.956	99.223	0.171	-	-
26-Sep-17	12.2	0	98.776	0.001	98.108	0.075	96.919	8.855	99.223	0.162	-	-
27-Sep-17	10.7	0	98.772	0.001	98.114	0.077	96.914	8.669	99.222	0.151	-	-
28-Sep-17	15.0	0	98.768	0.001	98.110	0.076	96.908	8.403	99.222	0.143	-	-
29-Sep-17	16.9	0	98.767	0.001	98.103	0.073	96.899	8.059	99.224	0.137	-	-
30-Sep-17	12.6	0	98.763	0.001	98.105	0.074	96.892	7.762	99.224	0.128	-	-
01-Oct-17	6.7	3.6	98.762	0.001	98.107	0.075	96.888	7.588	99.227	0.124	-	-
02-Oct-17	2.4	1.6	98.770	0.001	98.131	0.082	96.892	7.771	99.229	0.119	-	-
03-Oct-17	4.8	0	98.770	0.001	98.134	0.083	96.886	7.519	99.230	0.112	-	-
04-Oct-17	7.1	0	98.767	0.001	98.129	0.082	96.894	7.861	99.234	0.109	-	-
05-Oct-17	14.6	0	98.756	0.001	98.129	0.082	96.893	7.806	99.236	0.104	-	-
06-Oct-17	11.1	0	98.753	0.001	98.138	0.085	96.894	7.870	99.238	0.099	-	-
07-Oct-17	3.9	0	98.749	0.001	98.133	0.083	96.891	7.735	99.237	0.091	-	-
08-Oct-17	-0.4	0.6	98.748	0.001	98.145	0.087	96.894	7.840	99.235	0.082	-	-
09-Oct-17	1.0	1.4	98.745	0.001	98.147	0.087	96.891	7.745	99.234	0.075	-	-
10-Oct-17	2.0	0	98.745	0.001	98.151	0.089	96.897	7.970	99.237	0.072	-	-
11-Oct-17	0.2	0.8	98.744	0.001	98.174	0.095	96.894	7.874	99.236	0.066	-	-
12-Oct-17	-0.6	0	98.741	0.001	98.153	0.089	96.899	8.060	99.236	0.060	-	-
13-Oct-17	-1.2	0	98.738	0.001	98.160	0.091	96.902	8.208	99.234	0.053	-	-
14-Oct-17	0.3	0.2	98.736	0.001	98.158	0.091	96.905	8.316	99.234	0.049	-	-
15-Oct-17	2.2	1.2	98.739	0.001	98.153	0.089	96.896	7.974	99.233	0.044	-	-
16-Oct-17	6.9	0.2	98.747	0.001	98.162	0.092	96.904	8.284	99.236	0.041	-	-
17-Oct-17	5.0	11.6	98.756	0.002	98.150	0.088	96.897	7.983	99.235	0.037	-	-
18-Oct-17	0.7	6.8	98.809	0.002	98.212	0.104	96.930	9.398	99.249	0.041	-	-
19-Oct-17	4.1	0	99.023	0.014	98.225	0.108	96.980	11.688	99.245	0.035	-	-
20-Oct-17	3.5	0	99.026	0.015	98.218	0.106	97.015	13.481	99.244	0.030	-	-
21-Oct-17	0.1	0	99.040	0.017	98.210	0.104	97.036	14.575	99.243	0.028	-	-
22-Oct-17	-2.9	0	99.039	0.017	98.202	0.102	97.046	15.154	99.244	0.026	-	-
23-Oct-17	2.0	0	99.037	0.018	98.187	0.098	97.051	15.410	99.244	0.024	-	-
24-Oct-17	-	-	99.031	0.017	98.185	0.097	97.044	15.043	99.257	0.026	-	-
25-Oct-17	-	-	99.032	0.018	98.194	0.100	97.041	14.995	99.246	0.021	-	-
26-Oct-17	-	-	99.033	0.019	98.186	0.098	97.050	15.555	99.257	0.025	-	-
27-Oct-17	-	-	99.034	0.019	98.175	0.095	-	-	99.261	0.026	-	-
28-Oct-17	-	-	99.034	0.020	98.185	0.097	-	-	99.265	0.027	-	-
29-Oct-17	-	-	99.035	0.021	98.201	0.101	-	-	99.267	0.028	-	-
30-Oct-17	-	-	99.040	0.022	98.194	0.100	-	-	99.266	0.027	-	-
31-Oct-17	-	-	99.040	0.023	98.189	0.098	-	-	99.265	0.027	-	-
01-Nov-17	-	-	99.036	0.023	98.188	0.098	-	-	99.264	0.027	-	-
02-Nov-17	-	-	99.034	0.022	98.178	0.096	-	-	99.261	0.026	-	-
03-Nov-17	-	-	99.026	0.021	98.171	0.094	-	-	99.255	0.024	-	-
04-Nov-17	-	-	99.028	0.021	98.160	0.091	-	-	99.244	0.021	-	-
05-Nov-17	-	-	99.026	0.021	98.152	0.089	-	-	99.241	0.020	-	-
06-Nov-17	-	-	99.031	0.022	98.153	0.089	-	-	99.239	0.019	-	-
07-Nov-17	-	-	99.022	0.020	98.150	0.088	-	-	99.235	0.018	-	-
08-Nov-17	-	-	99.021	0.020	98.146	0.087	-	-	99.231	0.017	-	-
09-Nov-17	-	-	99.019	0.020	98.144	0.086	-	-	99.228	0.016	-	-
10-Nov-17	-	-	99.019	0.020	98.141	0.086	-	-	99.213	0.011	-	-
11-Nov-17	-	-	99.017	0.020	98.142	0.086	-	-	99.207	0.010	-	-
12-Nov-17	-	-	99.015	0.019	98.140	0.085	-	-	99.205	0.009	-	-
13-Nov-17	-	-	99.016	0.019	98.141	0.086	-	-	99.204	0.009	-	-
14-Nov-17	-	-	99.014	0.019	98.142	0.086	-	-	99.203	0.008	-	-
15-Nov-17	-	-	99.014	0.019	98.140	0.085	-	-	99.199	0.007	-	-
16-Nov-17	-	-	99.012	0.019	98.139	0.085	-	-	99.202	0.008	-	-
17-Nov-17	-	-	99.012	0.019	98.140	0.085	-	-	99.203	0.008	-	-
18-Nov-17	-	-	99.006	0.018	98.140	0.085	-	-	99.200	0.007	-	-
19-Nov-17	-	-	99.003	0.018	98.132	0.083	-	-	99.198	0.007	-	-
20-Nov-17	-	-	99.008	0.018	98.136	0.084	-	-	99.205	0.009	-	-
21-Nov-17	-	-	99.005	0.018	98.146	0.087	-	-	99.201	0.008	-	-
22-Nov-17	-	-	99.009	0.018	98.144	0.086	-	-	99.217	0.012	-	-
23-Nov-17	-	-	99.006	0.018	98.136	0.084	-	-	99.220	0.013	-	-
24-Nov-17	-	-	99.011	0.019	98.134	0.083	-	-	99.219	0.013	-	-
25-Nov-17	-	-	99.005	0.018	98.132	0.083	-	-	99.210	0.010	-	-
26-Nov-17	-	-	99.000	0.017	98.153	0.089	-	-	99.201	0.008	-	-
27-Nov-17	-	-	99.000	0.017	98.135	0.084	-	-	99.204	0.008	-	-
28-Nov-17	-	-	99.010	0.019	98.136	0.084	-	-	99.211	0.010	-	-
29-Nov-17	-	-	99.006	0.018	98.128	0.081	97.048	8.263	99.208	0.010	-	-
30-Nov-17	-	-	99.002	0.017	98.127	0.081	97.056	8.439	99.210	0.010	-	-
01-Dec-17	-	-	99.003	0.018	98.126	0.081	97.055	8.394	99.211	0.011	-	-
02-Dec-17	-	-	99.003	0.018	98.123	0.080	97.049	8.249	99.212	0.011	-	-
03-Dec-17	-	-	99.005	0.018	98.128	0.081	97.045	8.130	99.214	0.011	-	-
04-Dec-17	-	-	99.007	0.018	98.126	0.081	97.043	8.060	99.215	0.012	-	-
05-Dec-17	-	-	99.002	0.017	98.128	0.081	97.042	8.015	99.219	0.013	-	-
06-Dec-17	-	-	98.999	0.017	98.126	0.081	97.035	7.825	99.218	0.013	-	-
07-Dec-17	-	-	99.001	0.017	98.126	0.081	97.031	7.708	99.221	0.013	-	-
08-Dec-17	-	-	98.998	0.017	98.125	0.080	97.031	7.710	99.223	0.014	-	-
09-Dec-17	-	-	99.004	0.018	98.126	0.081	97.032	7.699	99.224	0.014	-	-
10-Dec-17	-	-	99.004	0.018	98.123	0.080	97.034	7.698	99.226	0.015	-	-
11-Dec-17	-	-	99.008	0.018	98.125	0.080	97.040	7.728	99.227	0.015	-	-
12-Dec-17	-	-	99.008	0.018	98.124	0.080	97.044	7.744	99.230	0.016	-	-
13-Dec-17	-	-	99.006	0.018	98.124	0.080	97.044	7.729	99.228	0.016	-	-
14-Dec-17	-	-	99.005	0.018	98.123	0.080	97.055	7.810	99.229	0.016	-	-
15-Dec-17	-	-	99.007	0.018	98.123	0.080	97.066	7.888	99.232	0.017	-	-
16-Dec-17	-	-	99.009	0.018	98.122	0.079	97.075	7.954	99.235	0.018	-	-
17-Dec-17	-	-	99.008	0.018	98.121	0.079	97.070	7.896	99.238	0.018	-	-
18-Dec-17	-	-	99.009	0.018	98.119	0.078	97.082	7.991	99.239	0.019	-	-
19-Dec-17	-	-	99.007	0.018	98.116	0.077	97.106	8.218	99.240	0.019	-	-
20-Dec-17	-	-	99.005	0.018	98.032	-	97.112	8.267	99.240	0.019	-	-
21-Dec-17	-	-	99.005	0.018	98.029	-	97.114	8.276	99.239	0.019	-	-
22-Dec-17	-	-	99.003	0.018	98.030	-	97.110	8.224	99.238	0.018	-	-
23-Dec-17	-	-	-	-	98.030	-	97.116	8.275	99.237	0.018	-	-
24-Dec-17	-	-	-	-	98.031	-	97.116	8.264	99.237	0.018	-	-
25-Dec-17	-	-	-	-	98.031	-	97.113	8.107	-	-	-	-
26-Dec-17	-	-	-	-	98.031	-	97.110	8.064	-	-	-	-
27-Dec-17	-	-	-	-	98.032	-	97.108	8.125	-	-	-	-
28-Dec-17	-	-	-	-	98.032	-	97.102	8.086	99.234	0.017	-	-
29-Dec-17	-	-	-	-	98.032	-	97.090	7.925	-	-	-	-
30-Dec-17	-	-	-	-	98.032	-	97.082	7.873	99.229	0.016	-	-
31-Dec-17	-	-	-	-	98.033	-	97.092	7.961	99.228	0.015	-	-
01-Jan-18	-19.3	-	-	-	-	-	97.059	7.631	99.228	0.015	-	-
02-Jan-18	-20.9	-	-	-	-	-	97.052	7.554	99.228	0.015	-	-
03-Jan-18	-17.5	-	-	-	-	-	97.049	7.514	99.227	0.015	-	-
04-Jan-18	-11.8	-	-	-	-	-	97.042	7.439	99.226	0.015	-	-
05-Jan-18	-10.4	-	-	-	-	-	97.038	7.400	99.226	0.015	-	-
06-Jan-18	-5.3	-	-	-	-	-	97.034	7.352	99.226	0.015	-	-
07-Jan-18	-9.1	-	-	-	-	-	97.043	7.406	99.227	0.015	-	-
08-Jan-18	-16.1	-	-	-	-	-	97.035	7.393	99.226	0.015	-	-
09-Jan-18	-25.0	-	-	-	-	-	97.036	7.408	99.226	0.015	-	-
10-Jan-18	-28.4	-	-	-	-	-	97.039	7.484	99.227	0.015	-	-
11-Jan-18	-30.4	-	-	-	-	-	97.035	7.344	-	-	-	-
12-Jan-18	-30.8	-	-	-	-	-	97.030	7.301	-	-	-	-
13-Jan-18	-21.6	-	-	-	-	-	97.026	7.179	99.214	0.011	-	-
14-Jan-18	-29.6	-	-	-	-	-	97.024	7.016	99.212	0.010	-	-
15-Jan-18	-13.1	-	-	-	-	-	97.016	6.772	99.214	0.011	-	-
16-Jan-18	-9.0	-	-	-	-	-	97.014	6.728	99.214	0.011	-	-
17-Jan-18	-7.3	-	-	-	-	-	97.012	6.656	99.215	0.011	-	-
18-Jan-18	-1.0	-	-	-	-	-	97.009	6.556	99.215	0.011	-	-
19-Jan-18	-5.5	-	-	-	-	-	97.004	6.400	99.216	0.011	-	-
20-Jan-18	-9.8	-	-	-	-	-	97.003	6.356	99.213	0.011	-	-
21-Jan-18	-16.9	-	-	-	-	-	97.004	6.368	99.213	0.011	-	-
22-Jan-18	-11.8	-	-	-	-	-	97.001	6.296	99.214	0.011	-	-
23-Jan-18	-10.7	-	-	-	-	-	97.001	6.491	99.214	0.011	-	-
24-Jan-18	-9.8	-	-	-	-	-	97.001	6.401	99.215	0.011	-	-
25-Jan-18	-13.9	-	-	-	-	-	97.005	6.365	99.215	0.011	-	-
26-Jan-18	-18.5	-	-	-	-	-	97.005	6.380	99.214	0.011	-	-
27-Jan-18	-25.6	-	-	-	-	-	97.005	6.365	99.213	0.010	-	-
28-Jan-18	-28.1	-	-	-	-	-	97.000	6.206	99.212	0.010	-	-
29-Jan-18	-21.7	-	-	-	-	-	96.991	5.934	99.209	0.009	-	-
30-Jan-18	-17.0	-	-	-	-	-	96.993	5.975	99.214	0.011	-	-
31-Jan-18	-24.7	-	-	-	-	-	96.992	5.931	99.210	0.010	-	-
01-Feb-18	-28.0	-	-	-	-	-	96.988	5.802	99.209	0.009	-	-
02-Feb-18	-32.3	-	-	-	-	-	96.980	5.591	99.208	0.009	-	-
03-Feb-18	-29.5	-	-	-	-	-	96.975	5.401	-	-	-	-
04-Feb-18	-18.2	-	-	-	-	-	96.972	5.338	99.207	0.009	-	-
05-Feb-18	-20.4	-	-	-	-	-	96.965	5.132	99.205	0.008	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
06-Feb-18	-21.0	-	-	-	-	-	96.963	5.061	99.207	0.008	-	-
07-Feb-18	-19.9	-	-	-	-	-	96.960	4.964	99.206	0.008	-	-
08-Feb-18	-16.2	-	99.043	0.024	-	-	96.957	4.893	99.204	0.008	-	-
09-Feb-18	-13.7	-	99.021	0.020	-	-	96.949	4.666	99.205	0.008	-	-
10-Feb-18	-14.0	-	99.004	0.018	-	-	96.948	4.621	99.206	0.008	-	-
11-Feb-18	-24.9	-	98.977	0.014	-	-	96.951	4.680	99.202	0.007	-	-
12-Feb-18	-14.0	-	98.990	0.016	-	-	96.953	4.715	99.203	0.007	-	-
13-Feb-18	-3.9	-	98.982	0.015	-	-	96.954	4.750	99.206	0.008	-	-
14-Feb-18	-22.3	-	98.933	0.010	-	-	96.954	4.733	99.203	0.007	-	-
15-Feb-18	-16.6	-	98.915	0.009	-	-	96.955	4.743	99.202	0.007	-	-
16-Feb-18	-20.4	-	98.896	0.007	-	-	96.957	4.781	99.204	0.007	-	-
17-Feb-18	-16.3	-	98.896	0.007	-	-	96.958	4.793	99.203	0.007	-	-
18-Feb-18	-21.4	-	98.860	0.006	-	-	96.961	4.861	99.201	0.007	-	-
19-Feb-18	-16.0	-	98.846	0.005	-	-	96.959	4.818	99.205	0.008	-	-
20-Feb-18	-25.3	-	98.835	0.005	-	-	96.961	4.860	99.197	0.005	-	-
21-Feb-18	-15.0	-	98.820	0.004	-	-	96.964	4.944	99.209	0.009	-	-
22-Feb-18	-9.2	-	98.814	0.004	-	-	96.965	4.947	99.196	0.005	-	-
23-Feb-18	-5.0	-	98.804	0.004	-	-	96.961	4.816	99.194	0.004	-	-
24-Feb-18	-10.4	-	98.800	0.003	-	-	96.964	4.920	99.198	0.006	-	-
25-Feb-18	-8.8	-	98.796	0.003	-	-	96.963	4.876	99.202	0.007	-	-
26-Feb-18	-8.5	-	98.792	0.003	-	-	96.965	4.923	99.200	0.006	-	-
27-Feb-18	-1.3	-	98.788	0.003	-	-	96.966	4.940	99.200	0.006	-	-
28-Feb-18	-11.1	-	98.783	0.003	-	-	96.966	4.928	99.199	0.006	-	-
01-Mar-18	-18.6	-	98.776	0.003	-	-	96.965	4.885	99.196	0.005	-	-
02-Mar-18	-17.8	-	98.766	0.003	-	-	96.963	4.842	99.197	0.005	-	-
03-Mar-18	-9.9	-	98.762	0.002	-	-	96.963	4.830	99.198	0.006	-	-
04-Mar-18	-6.9	-	98.756	0.002	-	-	96.962	4.787	99.197	0.005	-	-
05-Mar-18	-7.1	-	98.751	0.002	-	-	96.960	4.714	99.196	0.005	-	-
06-Mar-18	-9.2	-	98.746	0.002	-	-	96.965	4.857	99.200	0.006	-	-
07-Mar-18	-9.4	-	98.740	0.002	-	-	96.967	4.888	99.194	0.004	-	-
08-Mar-18	-6.7	-	98.735	0.002	-	-	96.964	4.835	99.196	0.005	-	-
09-Mar-18	-4.2	-	98.730	0.002	-	-	-	-	99.197	0.005	-	-
10-Mar-18	-2.5	-	98.724	0.002	-	-	-	-	99.193	0.005	-	-
11-Mar-18	0.3	-	98.718	0.002	-	-	-	-	99.195	0.007	-	-
12-Mar-18	5.2	-	98.713	0.002	-	-	-	-	99.201	0.010	-	-
13-Mar-18	5.0	-	98.709	0.002	-	-	-	-	99.199	0.011	-	-
14-Mar-18	4.9	-	98.706	0.002	-	-	-	-	99.189	0.009	-	-
15-Mar-18	2.7	-	98.707	0.002	-	-	-	-	99.195	0.012	-	-
16-Mar-18	2.0	-	98.708	0.002	-	-	-	-	99.195	0.013	-	-
17-Mar-18	-3.1	-	98.711	0.002	-	-	-	-	99.200	0.016	-	-
18-Mar-18	-4.6	-	98.715	0.002	-	-	-	-	99.200	0.018	-	-
19-Mar-18	-0.7	-	98.719	0.002	-	-	-	-	99.201	0.019	-	-
20-Mar-18	0.1	-	98.722	0.002	-	-	-	-	99.205	0.022	-	-
21-Mar-18	-8.0	-	98.724	0.003	-	-	-	-	99.206	0.024	-	-
22-Mar-18	-8.0	-	98.723	0.003	-	-	-	-	99.206	0.025	-	-
23-Mar-18	-2.4	-	98.724	0.003	-	-	-	-	99.208	0.027	-	-
24-Mar-18	-5.6	-	98.728	0.003	-	-	-	-	99.208	0.028	-	-
25-Mar-18	-14.0	-	98.729	0.003	-	-	-	-	99.208	0.030	-	-
26-Mar-18	-14.2	-	98.726	0.003	-	-	-	-	99.211	0.034	-	-
27-Mar-18	-17.3	-	98.721	0.003	-	-	-	-	99.209	0.035	-	-
28-Mar-18	-15.3	-	98.717	0.003	-	-	-	-	99.209	0.038	-	-
29-Mar-18	-19.8	-	98.700	0.003	-	-	-	-	99.207	0.039	-	-
30-Mar-18	-18.5	-	98.697	0.003	-	-	-	-	99.206	0.041	-	-
31-Mar-18	-6.9	-	98.694	0.003	-	-	-	-	99.206	0.044	-	-
01-Apr-18	-7.6	-	98.689	0.003	-	-	-	-	99.207	0.048	-	-
02-Apr-18	-11.2	-	98.682	0.003	-	-	-	-	99.205	0.050	-	-
03-Apr-18	-15.1	-	98.676	0.003	-	-	-	-	99.204	0.052	-	-
04-Apr-18	-14.9	-	98.669	0.003	-	-	-	-	99.206	0.057	-	-
05-Apr-18	-14.3	-	98.663	0.002	-	-	-	-	99.205	0.060	-	-
06-Apr-18	-11.4	-	98.655	0.002	-	-	-	-	99.205	0.064	-	-
07-Apr-18	-6.3	-	98.648	0.002	-	-	-	-	99.205	0.067	-	-
08-Apr-18	-3.8	-	98.642	0.002	-	-	-	-	99.205	0.071	-	-
09-Apr-18	-2.7	-	98.637	0.002	-	-	-	-	99.203	0.073	-	-
10-Apr-18	-6.4	-	98.633	0.002	-	-	-	-	99.203	0.078	-	-
11-Apr-18	-8.1	-	98.630	0.002	-	-	-	-	99.203	0.082	-	-
12-Apr-18	-5.9	-	98.629	0.002	-	-	-	-	99.205	0.088	-	-
13-Apr-18	1.4	-	98.627	0.002	-	-	-	-	99.205	0.093	-	-
14-Apr-18	-	-	98.633	0.003	-	-	-	-	99.208	0.101	-	-
15-Apr-18	-	-	98.659	0.003	-	-	-	-	99.214	0.112	-	-
16-Apr-18	-	-	98.751	0.007	-	-	-	-	99.236	0.144	-	-
17-Apr-18	-	-	98.810	0.012	-	-	-	-	99.256	0.177	-	-
18-Apr-18	-	-	98.874	0.019	-	-	-	-	99.265	0.197	-	-
19-Apr-18	-	-	99.023	0.064	-	-	-	-	99.308	0.278	-	-
20-Apr-18	-	-	99.089	0.110	-	-	-	-	99.414	0.542	-	-
21-Apr-18	-	-	99.125	0.148	-	-	-	-	99.522	0.917	-	-
22-Apr-18	-	-	99.130	0.154	-	-	-	-	99.510	0.889	-	-
23-Apr-18	-	-	99.109	0.131	-	-	-	-	99.510	0.906	-	-
24-Apr-18	-	-	99.101	0.124	-	-	-	-	99.530	1.003	-	-
25-Apr-18	-	-	99.114	0.138	-	-	-	-	99.531	1.025	-	-
26-Apr-18	-	-	99.106	0.130	-	-	-	-	99.543	1.095	-	-
27-Apr-18	-	-	99.098	0.122	-	-	-	-	99.541	1.106	-	-
28-Apr-18	-	-	99.097	0.122	-	-	-	-	99.577	1.292	-	-
29-Apr-18	-	-	99.092	0.118	-	-	-	-	99.602	1.440	-	-
30-Apr-18	-	-	99.089	0.116	-	-	-	-	99.655	1.755	-	-
01-May-18	-	-	99.072	0.101	-	-	-	-	99.673	1.886	-	-
02-May-18	-	-	99.070	0.100	-	-	-	-	99.682	1.967	-	-
03-May-18	-	-	99.063	0.095	-	-	-	-	99.689	2.038	-	-
04-May-18	-	-	99.057	0.091	-	-	-	-	99.691	2.079	-	-
05-May-18	-	-	99.053	0.089	-	-	-	-	99.691	2.108	-	-
06-May-18	-	-	99.047	0.085	-	-	-	-	99.680	2.067	-	-
07-May-18	-	-	99.037	0.079	-	-	-	-	99.668	2.021	-	-
08-May-18	-	-	99.035	0.078	-	-	-	-	99.658	1.987	-	-
09-May-18	-	-	99.032	0.077	-	-	-	-	99.637	1.888	-	-
10-May-18	-	-	99.028	0.075	-	-	-	-	99.616	1.792	-	-
11-May-18	-	-	99.020	0.070	-	-	-	-	99.594	1.694	-	-
12-May-18	-	-	99.017	0.069	-	-	-	-	99.570	1.585	-	-
13-May-18	-	-	99.014	0.068	-	-	-	-	99.547	1.486	-	-
14-May-18	-	-	99.013	0.067	-	-	-	-	99.520	1.370	-	-
15-May-18	-	-	99.012	0.067	-	-	97.420	36.289	99.500	1.294	-	-
16-May-18	-	-	99.010	0.067	-	-	97.379	32.911	99.471	1.158	-	-
17-May-18	-	-	99.012	0.068	-	-	97.343	30.074	99.449	1.039	-	-
18-May-18	-	-	98.990	0.057	-	-	97.313	27.877	99.429	0.935	-	-
19-May-18	-	-	98.992	0.057	-	-	97.287	25.975	99.428	0.909	-	-
20-May-18	-	-	98.994	0.058	-	-	97.256	23.793	99.426	0.879	-	-
21-May-18	-	-	98.991	0.056	-	-	97.230	22.034	99.396	0.751	-	-
22-May-18	-	-	98.990	0.055	-	-	97.204	20.339	99.363	0.625	-	-
23-May-18	-	-	98.987	0.053	99.349	0.051	97.178	18.711	99.330	0.512	-	-
24-May-18	-	-	98.986	0.052	99.339	0.047	97.154	17.323	99.315	0.457	-	-
25-May-18	-	-	98.984	0.051	99.333	0.045	97.131	15.988	99.298	0.400	-	-
26-May-18	-	-	98.990	0.053	99.339	0.047	97.115	15.087	99.283	0.352	-	-
27-May-18	-	-	98.986	0.051	99.347	0.050	97.124	15.576	99.267	0.305	-	-
28-May-18	-	-	98.992	0.053	99.334	0.046	97.118	15.234	99.251	0.262	-	-
29-May-18	-	-	98.990	0.052	99.326	0.043	97.107	14.624	99.237	0.228	-	-
30-May-18	-	-	98.987	0.050	99.323	0.043	97.094	13.972	99.217	0.187	-	-
31-May-18	-	-	98.986	0.049	99.320	0.042	97.081	13.283	99.203	0.159	-	-
01-Jun-18	-	-	98.993	0.052	99.313	0.040	97.059	12.161	99.226	0.183	-	-
02-Jun-18	-	-	98.994	0.052	99.318	0.041	97.046	11.518	99.234	0.187	-	-
03-Jun-18	-	-	98.994	0.051	99.325	0.043	97.044	11.414	99.251	0.204	-	-
04-Jun-18	-	-	98.990	0.049	99.326	0.043	97.047	11.550	99.272	0.228	-	-
05-Jun-18	-	-	99.001	0.054	99.376	0.065	97.061	12.278	99.302	0.271	-	-
06-Jun-18	-	-	99.014	0.070	99.399	0.085	97.089	13.701	99.317	0.289	-	-
07-Jun-18	-	-	99.012	0.067	99.392	0.078	97.106	14.598	99.321	0.285	-	-
08-Jun-18	-	-	99.012	0.066	99.376	0.065	97.110	14.806	99.326	0.284	-	-
09-Jun-18	-	-	99.009	0.062	99.360	0.055	97.102	14.365	99.340	0.300	-	-
10-Jun-18	-	-	99.004	0.055	99.346	0.049	97.085	13.458	99.337	0.283	-	-
11-Jun-18	-	-	99.005	0.056	99.351	0.051	97.074	12.934	99.355	0.307	-	-
12-Jun-18	-	-	99.006	0.057	99.351	0.051	97.064	12.420	99.352	0.289	-	-
13-Jun-18	-	-	99.022	0.078	-	-	97.105	14.545	99.388	0.353	-	-
14-Jun-18	-	-	99.030	0.091	-	-	97.158	17.533	99.403	0.374	-	-
15-Jun-18	-	-	99.026	0.084	-	-	97.185	19.154	99.406	0.367	-	-
16-Jun-18	-	-	99.023	0.078	-	-	97.199	20.017	99.406	0.356	-	-
17-Jun-18	-	-	99.022	0.076	-	-	97.192	19.568	99.407	0.350	-	-
18-Jun-18	-	-	99.014	0.064	-	-	97.174	18.512	99.409	0.346	-	-
19-Jun-18	-	-	99.013	0.062	-	-	97.139	16.438	99.399	0.317	-	-
20-Jun-18	-	-	99.010	0.058	-	-	97.103	14.429	99.392	0.295	-	-
21-Jun-18	-	-	99.005	0.051	-	-	97.072	12.800	99.379	0.263	-	-
22-Jun-18	-	-	99.003	0.049	-	-	97.054	11.893	99.369	0.238	-	-
23-Jun-18	-	-	99.008	0.054	-	-	97.036	11.020	99.365	0.226	-	-
24-Jun-18	-	-	99.005	0.050	-	-	97.028	10.684	99.367	0.223	-	-
25-Jun-18	-	-	99.007	0.052	-	-	97.015	10.080	99.377	0.233	-	-
26-Jun-18	-	-	99.005	0.049	-	-	97.016	10.118	99.398	0.264	-	-
27-Jun-18	-	-	99.004	0.047	-	-	97.029	10.707	99.405	0.270	-	-
28-Jun-18	-	-	99.023	0.073	-	-	97.057	12.042	99.459	0.376	-	-
29-Jun-18	-	-	99.030	0.084	-	-	97.080	13.193	99.472	0.398	-	-
30-Jun-18	-	-	99.022	0.070	-	-	97.132	16.050	99.504	0.470	-	-
01-Jul-18	-	-	99.020	0.067	-	-	97.157	17.487	99.509	0.473	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
02-Jul-18	-	-	99.015	0.059	-	-	97.156	17.418	99.506	0.456	-	-
03-Jul-18	-	-	99.010	0.052	-	-	97.160	17.645	99.512	0.462	-	-
04-Jul-18	-	-	99.069	0.171	-	-	97.229	21.954	99.537	0.519	-	-
05-Jul-18	-	-	99.024	0.071	-	-	97.264	24.308	99.541	0.520	-	-
06-Jul-18	-	-	99.018	0.061	-	-	97.263	24.296	99.559	0.560	-	-
07-Jul-18	-	-	99.013	0.054	-	-	97.253	23.598	99.564	0.564	-	-
08-Jul-18	-	-	99.014	0.055	-	-	97.244	22.976	99.568	0.565	-	-
09-Jul-18	-	-	99.014	0.054	-	-	97.232	22.164	99.565	0.546	-	-
10-Jul-18	-	-	99.014	0.054	-	-	97.204	20.338	99.549	0.491	-	-
11-Jul-18	-	-	99.009	0.047	-	-	97.168	18.104	99.541	0.461	-	-
12-Jul-18	-	-	99.004	0.041	-	-	97.131	15.996	99.518	0.394	-	-
13-Jul-18	-	-	99.004	0.040	-	-	97.097	14.120	99.497	0.338	-	-
14-Jul-18	-	-	99.003	0.038	-	-	97.075	12.964	99.480	0.295	-	-
15-Jul-18	-	-	99.002	0.037	-	-	97.056	12.003	99.461	0.251	-	-
16-Jul-18	-	-	99.002	0.036	-	-	97.051	11.750	99.449	0.225	-	-
17-Jul-18	-	-	99.003	0.037	-	-	97.039	11.165	99.440	0.204	-	-
18-Jul-18	-	-	98.999	0.033	-	-	97.017	10.181	99.423	0.173	-	-
19-Jul-18	-	-	99.001	0.034	-	-	96.997	9.284	99.413	0.155	-	-
20-Jul-18	-	-	99.001	0.033	-	-	96.976	8.386	99.409	0.145	-	-
21-Jul-18	-	-	98.998	0.031	-	-	96.959	7.690	99.401	0.130	-	-
22-Jul-18	-	-	99.006	0.038	-	-	96.980	8.539	99.458	0.204	-	-
23-Jul-18	-	-	99.003	0.034	-	-	97.038	11.118	99.459	0.200	-	-
24-Jul-18	-	-	99.032	0.076	-	-	97.118	15.271	99.474	0.217	-	-
25-Jul-18	-	-	99.031	0.074	-	-	97.180	18.874	99.474	0.211	-	-
26-Jul-18	-	-	99.025	0.063	-	-	97.193	19.669	99.481	0.217	-	-
27-Jul-18	-	-	99.020	0.055	-	-	97.184	19.100	99.511	0.262	-	-
28-Jul-18	-	-	99.014	0.046	-	-	97.165	17.937	99.501	0.238	-	-
29-Jul-18	-	-	99.008	0.037	-	-	97.139	16.406	99.482	0.201	-	-
30-Jul-18	-	-	99.004	0.032	-	-	97.107	14.669	99.467	0.173	-	-
31-Jul-18	-	-	98.999	0.027	-	-	97.081	13.284	99.454	0.151	-	-
01-Aug-18	-	-	98.998	0.026	-	-	97.054	11.915	99.447	0.137	-	-
02-Aug-18	-	-	98.995	0.024	-	-	97.033	10.899	99.451	0.137	-	-
03-Aug-18	-	-	99.003	0.029	-	-	97.027	10.612	99.448	0.129	-	-
04-Aug-18	-	-	98.995	0.023	-	-	97.012	9.920	99.436	0.111	-	-
05-Aug-18	-	-	98.991	0.021	-	-	96.991	9.035	99.434	0.105	-	-
06-Aug-18	-	-	98.988	0.019	-	-	96.978	8.478	99.429	0.096	-	-
07-Aug-18	-	-	98.991	0.020	-	-	96.969	8.101	99.431	0.094	-	-
08-Aug-18	-	-	98.991	0.019	-	-	96.957	7.613	99.427	0.086	-	-
09-Aug-18	-	-	98.991	0.019	-	-	96.942	7.026	99.422	0.078	-	-
10-Aug-18	-	-	98.987	0.017	-	-	96.933	6.682	99.415	0.069	-	-
11-Aug-18	-	-	98.986	0.016	-	-	96.920	6.238	99.414	0.065	-	-
12-Aug-18	-	-	98.983	0.014	-	-	96.908	5.809	99.409	0.058	-	-
13-Aug-18	-	-	98.978	0.011	-	-	96.898	5.462	99.404	0.052	-	-
14-Aug-18	-	-	98.977	0.010	-	-	96.889	5.158	99.413	0.055	-	-
15-Aug-18	-	-	98.975	0.009	-	-	96.882	4.926	99.392	0.039	-	-
16-Aug-18	-	-	98.970	0.007	-	-	96.871	4.575	99.399	0.041	-	-
17-Aug-18	-	-	98.969	0.006	-	-	96.867	4.447	99.402	0.040	-	-
18-Aug-18	-	-	98.969	0.005	-	-	96.862	4.321	99.389	0.031	-	-
19-Aug-18	-	-	98.967	0.004	-	-	96.853	4.050	99.392	0.031	-	-
20-Aug-18	-	-	98.970	0.005	-	-	96.844	3.788	99.395	0.030	-	-
21-Aug-18	-	-	98.966	0.003	-	-	96.843	3.755	99.405	0.034	-	-
22-Aug-18	-	-	98.964	0.002	-	-	96.840	3.667	99.421	0.041	-	-
23-Aug-18	-	-	98.964	0.001	-	-	96.840	3.662	99.448	0.057	-	-
24-Aug-18	-	-	-	-	99.316	0.010	96.855	4.114	99.459	0.063	-	-
25-Aug-18	-	-	98.428	0.002	99.322	0.010	96.868	4.499	99.472	0.071	-	-
26-Aug-18	-	-	98.429	0.002	99.328	0.011	96.878	4.805	99.480	0.075	-	-
27-Aug-18	-	-	98.429	0.002	99.326	0.010	96.891	5.219	99.482	0.074	-	-
28-Aug-18	-	-	98.422	0.002	99.325	0.010	96.890	5.181	99.481	0.070	-	-
29-Aug-18	-	-	98.428	0.002	99.323	0.010	96.891	5.208	99.488	0.073	-	-
30-Aug-18	-	-	98.441	0.003	99.329	0.011	96.896	5.402	99.511	0.091	-	-
31-Aug-18	-	-	98.530	0.010	99.390	0.036	96.927	6.481	99.548	0.128	-	-
01-Sep-18	-	-	98.669	0.021	99.401	0.044	96.958	7.656	99.565	0.145	-	-
02-Sep-18	-	-	98.596	0.015	99.409	0.052	96.973	8.254	99.589	0.172	-	-
03-Sep-18	-	-	98.612	0.017	99.412	0.055	96.977	8.412	99.605	0.190	-	-
04-Sep-18	-	-	98.578	0.014	99.422	0.067	96.986	8.782	99.615	0.200	-	-
05-Sep-18	-	-	98.595	0.015	99.415	0.058	96.985	8.776	99.633	0.223	-	-
06-Sep-18	-	-	98.561	0.013	99.412	0.055	96.980	8.503	99.643	0.234	-	-
07-Sep-18	-	-	98.548	0.012	99.408	0.051	96.973	8.146	99.651	0.242	-	-
08-Sep-18	-	-	98.540	0.011	99.402	0.045	96.965	7.757	99.653	0.240	-	-
09-Sep-18	-	-	98.666	0.021	99.440	0.095	96.977	8.175	99.670	0.264	-	-
10-Sep-18	-	-	98.798	0.032	99.473	0.181	97.023	10.085	99.682	0.280	-	-
11-Sep-18	-	-	98.755	0.028	99.479	0.204	97.062	11.844	99.699	0.307	-	-
12-Sep-18	-	-	98.767	0.029	99.490	0.254	97.078	12.556	99.709	0.321	-	-
13-Sep-18	-	-	98.766	0.029	99.495	0.281	97.087	12.928	99.722	0.341	-	-
14-Sep-18	-	-	98.750	0.028	99.489	0.249	97.095	13.254	99.732	0.356	-	-
15-Sep-18	-	-	98.734	0.026	99.492	0.264	97.092	13.015	99.735	0.355	-	-
16-Sep-18	-	-	98.723	0.025	99.477	0.196	97.086	12.627	99.740	0.358	-	-
17-Sep-18	-	-	98.711	0.025	99.465	0.155	97.077	12.095	99.742	0.355	-	-
18-Sep-18	-	-	98.703	0.024	99.458	0.135	97.068	11.575	99.747	0.358	-	-
19-Sep-18	-	-	98.692	0.023	99.450	0.116	97.060	11.113	99.744	0.344	-	-
20-Sep-18	-	-	98.691	0.023	99.445	0.105	97.057	10.893	99.747	0.343	-	-
21-Sep-18	-	-	98.672	0.021	99.438	0.092	97.045	10.262	99.745	0.331	-	-
22-Sep-18	-	-	98.663	0.021	99.429	0.077	97.043	10.096	99.745	0.323	-	-
23-Sep-18	-	-	98.663	0.021	99.427	0.074	97.034	9.619	99.744	0.314	-	-
24-Sep-18	-	-	98.673	0.022	99.427	0.074	97.027	9.241	99.746	0.311	-	-
25-Sep-18	-	-	98.662	0.021	99.422	0.067	97.020	8.869	99.745	0.302	-	-
26-Sep-18	-	-	98.663	0.021	99.420	0.064	97.018	8.699	99.745	0.295	-	-
27-Sep-18	-	-	98.664	0.021	99.420	0.064	97.013	8.421	99.745	0.288	-	-
28-Sep-18	-	-	98.591	0.018	99.419	0.063	97.013	8.351	99.746	0.283	-	-
29-Sep-18	-	-	98.658	0.020	99.419	0.063	97.009	8.125	99.748	0.280	-	-
30-Sep-18	-	-	98.645	0.019	99.416	0.060	97.007	7.980	99.746	0.270	-	-
01-Oct-18	-	-	98.641	0.019	99.415	0.058	97.006	7.873	99.746	0.263	-	-
02-Oct-18	-	-	98.641	0.019	99.413	0.056	97.007	7.836	99.751	0.266	-	-
03-Oct-18	-	-	98.637	0.019	99.416	0.060	97.005	7.799	99.751	0.260	-	-
04-Oct-18	-	-	98.631	0.018	99.414	0.057	97.055	7.838	99.746	0.244	-	-
05-Oct-18	-	-	98.634	0.018	99.412	0.054	97.016	8.159	99.743	0.233	-	-
06-Oct-18	-	-	98.629	0.018	99.416	0.052	97.047	8.276	99.741	0.224	-	-
07-Oct-18	-	-	98.604	0.016	99.408	0.048	96.995	8.286	99.741	0.218	-	-
08-Oct-18	-	-	98.598	0.016	99.409	0.045	96.991	8.392	99.741	0.213	-	-
09-Oct-18	-	-	98.586	0.015	99.399	0.041	97.183	8.634	99.737	0.201	-	-
10-Oct-18	-	-	98.565	0.013	99.390	0.037	97.142	8.840	99.733	0.190	-	-
11-Oct-18	-	-	98.560	0.013	99.388	0.034	97.058	9.559	99.732	0.185	-	-
12-Oct-18	-	-	98.564	0.013	99.387	0.034	96.991	10.015	99.731	0.184	-	-
13-Oct-18	-	-	98.564	0.013	99.389	0.035	96.992	10.575	99.729	0.181	-	-
14-Oct-18	-	-	98.559	0.013	99.391	0.037	97.098	11.012	99.727	0.178	-	-
15-Oct-18	-	-	98.564	0.013	99.393	0.038	96.987	11.645	99.731	0.184	-	-
16-Oct-18	-	-	98.583	0.014	99.395	0.040	96.962	11.200	99.729	0.181	-	-
17-Oct-18	-	-	98.552	0.012	99.396	0.042	96.972	11.013	99.730	0.182	-	-
18-Oct-18	-	-	98.575	0.014	99.403	0.046	96.986	10.868	99.727	0.178	-	-
19-Oct-18	-	-	98.590	0.015	99.413	0.056	96.995	10.662	99.727	0.178	-	-
20-Oct-18	-	-	98.586	0.015	99.415	0.058	96.988	10.320	99.726	0.177	-	-
21-Oct-18	-	-	98.610	0.017	99.420	0.064	96.999	10.030	99.730	0.182	-	-
22-Oct-18	-	-	98.588	0.015	99.418	0.062	96.992	9.782	99.726	0.177	-	-
23-Oct-18	-	-	98.575	0.014	99.413	0.058	97.000	9.493	99.726	0.177	-	-
24-Oct-18	-	-	98.585	0.015	99.417	0.059	96.989	9.175	99.723	0.172	-	-
25-Oct-18	-	-	98.585	0.015	99.409	0.054	96.984	8.835	99.722	0.171	-	-
26-Oct-18	-	-	98.567	0.013	99.409	0.053	96.982	8.532	99.722	0.171	-	-
27-Oct-18	-	-	98.567	0.013	99.408	0.052	96.980	8.221	99.720	0.168	-	-
28-Oct-18	-	-	98.563	0.013	99.407	0.050	96.982	7.951	99.719	0.167	-	-
29-Oct-18	-	-	98.573	0.014	99.402	0.047	96.983	7.851	99.718	0.165	-	-
30-Oct-18	-	-	98.579	0.014	99.400	0.045	96.973	7.664	99.718	0.165	-	-
31-Oct-18	-	-	98.536	0.011	99.404	0.046	96.975	7.609	99.716	0.163	-	-
01-Nov-18	-	-	98.547	0.012	99.410	0.048	96.923	7.426	99.716	0.163	-	-
02-Nov-18	-	-	98.550	0.012	99.396	0.041	96.962	7.331	99.713	0.159	-	-
03-Nov-18	-	-	98.539	0.011	99.395	0.039	96.925	6.909	99.711	0.156	-	-
04-Nov-18	-	-	98.541	0.011	99.400	0.040	96.959	7.152	99.710	0.155	-	-
05-Nov-18	-	-	98.527	0.010	99.394	0.037	96.955	6.726	99.706	0.149	-	-
06-Nov-18	-	-	98.518	0.009	99.389	0.035	96.951	6.921	99.700	0.142	-	-
07-Nov-18	-	-	98.515	0.009	99.381	0.030	96.969	7.025	99.695	0.135	-	-
08-Nov-18	-	-	98.517	0.009	99.368	0.023	96.986	7.132	99.690	0.129	-	-
09-Nov-18	-	-	98.545	0.011	99.351	0.017	96.974	6.929	99.684	0.122	-	-
10-Nov-18	-	-	98.501	0.008	99.347	0.015	96.938	6.499	99.671	0.108	-	-
11-Nov-18	-	-	98.491	0.007	99.346	0.015	96.944	6.478	99.659	0.095	-	-
12-Nov-18	-	-	98.491	0.007	99.356	0.018	96.954	6.503	99.659	0.095	-	-
13-Nov-18	-	-	98.480	0.006	99.363	0.021	96.950	6.274	99.653	0.089	-	-
14-Nov-18	-	-	98.496	0.008	99.366	0.022	96.947	6.221	99.652	0.088	-	-
15-Nov-18	-	-	98.480	0.006	99.371	0.025	96.941	6.153	99.636	0.073	-	-
16-Nov-18	-	-	98.492	0.007	99.371	0.025	96.929	5.972	99.666	0.102	-	-
17-Nov-18	-	-	98.478	0.006	99.369	0.024	96.925	5.856	99.659	0.095	-	-
18-Nov-18	-	-	98.475	0.006	99.368	0.023	96.919	5.734	99.630	0.068	-	-
19-Nov-18	-	-	98.463	0.005	99.370	0.024	96.908	5.562	99.572	0.029	-	-
20-Nov-18	-	-	98.460	0.005	99.371	0.025	96.950	5.701	99.547	0.022	-	-
21-Nov-18	-	-	98.464	0.005	99.379	0.029	96.928	5.592	99.576	0.031	-	-
22-Nov-18	-	-	98.461	0.005	99.384	0.032	96.899	5.269	99.581	0.034	-	-
23-Nov-18	-	-	98.465	0.005	99.386	0.033	96.976	5.269	99.578	0.032	-	-
24-Nov-18	-	-	98.457	0.005	99.391	0.037	96.878	4.955	99.582	0.034	-	-

Table I-1: Daily Datasets for Kearl Climate and Hydrometric Stations

Date	Station C4		Station K6		Station K9		Station K10		Station K11		Station K7	
Day Month	Air temperature (°C)	Rainfall total (mm)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)	Water level (m)	Discharge (m3/s)
25-Nov-18	-	-	98.455	0.004	99.391	0.037	96.950	5.159	99.608	0.051	-	-
26-Nov-18	-	-	98.452	0.004	99.392	0.037	96.986	5.038	99.622	0.061	-	-
27-Nov-18	-	-	98.452	0.004	99.394	0.039	96.989	4.918	99.627	0.065	-	-
28-Nov-18	-	-	98.452	0.004	99.398	0.042	96.992	4.797	99.627	0.065	-	-
29-Nov-18	-	-	98.453	0.004	99.403	0.046	96.995	4.677	99.597	0.043	-	-
30-Nov-18	-	-	98.452	0.004	99.404	0.047	96.999	4.557	99.585	0.036	-	-
01-Dec-18	-	-	98.450	0.004	99.405	0.048	97.001	4.436	99.579	0.033	-	-
02-Dec-18	-	-	98.450	0.004	99.407	0.050	97.004	4.316	99.580	0.033	-	-
03-Dec-18	-	-	98.453	0.004	99.405	0.048	96.818	4.045	99.582	0.034	-	-
04-Dec-18	-	-	98.451	0.004	99.403	0.046	96.875	4.185	99.589	0.038	-	-
05-Dec-18	-	-	98.448	0.004	99.405	0.048	96.907	4.186	99.586	0.037	-	-
06-Dec-18	-	-	98.453	0.004	99.404	0.047	96.961	3.972	99.548	0.022	-	-
07-Dec-18	-	-	98.458	0.005	99.407	0.050	96.882	4.009	99.549	0.022	-	-
08-Dec-18	-	-	98.462	0.005	99.407	0.050	96.833	3.707	99.548	0.022	-	-
09-Dec-18	-	-	98.459	0.005	99.409	0.052	96.834	3.746	99.546	0.022	-	-
10-Dec-18	-	-	98.455	0.004	99.409	0.052	96.835	3.563	99.554	0.024	-	-
11-Dec-18	-	-	98.458	0.005	99.413	0.056	96.900	3.479	99.554	0.024	-	-
12-Dec-18	-	-	98.467	0.005	99.415	0.058	96.950	3.380	99.562	0.026	-	-
13-Dec-18	-	-	98.461	0.005	99.415	0.058	97.060	3.281	99.558	0.025	-	-
14-Dec-18	-	-	98.449	0.004	99.412	0.055	96.795	3.169	99.555	0.024	-	-
15-Dec-18	-	-	98.447	0.004	99.410	0.053	96.951	3.249	99.555	0.024	-	-
16-Dec-18	-	-	98.446	0.004	99.412	0.055	96.748	2.905	99.553	0.024	-	-
17-Dec-18	-	-	98.445	0.004	99.412	0.055	96.757	2.852	99.559	0.025	-	-
18-Dec-18	-	-	98.443	0.003	99.419	0.063	96.800	2.995	99.559	0.025	-	-
19-Dec-18	-	-	98.442	0.003	99.421	0.066	96.938	2.893	99.559	0.025	-	-
20-Dec-18	-	-	98.444	0.003	99.422	0.067	96.746	2.601	99.557	0.025	-	-
21-Dec-18	-	-	98.443	0.003	99.423	0.068	96.800	2.549	99.552	0.023	-	-
22-Dec-18	-	-	98.445	0.004	99.425	0.071	96.913	2.496	99.549	0.022	-	-
23-Dec-18	-	-	98.443	0.003	99.426	0.071	96.707	2.285	99.543	0.021	-	-
24-Dec-18	-	-	98.441	0.003	99.422	0.067	96.721	2.243	99.554	0.024	-	-
25-Dec-18	-	-	98.438	0.003	99.419	0.063	96.707	2.134	99.551	0.023	-	-
26-Dec-18	-	-	98.436	0.003	99.416	0.060	96.706	2.057	99.538	0.019	-	-
27-Dec-18	-	-	-	-	99.411	0.054	96.698	1.964	99.537	0.019	-	-
28-Dec-18	-	-	-	-	99.411	0.054	96.691	1.872	99.544	0.021	-	-
29-Dec-18	-	-	-	-	99.407	0.050	96.693	1.802	99.558	0.025	-	-
30-Dec-18	-	-	-	-	99.409	0.052	96.675	1.684	99.529	0.016	-	-
31-Dec-18	-	-	-	-	99.407	0.050	96.661	1.576	99.560	0.026	-	-

\- = no data

APPENDIX II

Kearl Hydrometric Station Stage-Discharge Rating Curves

STATION NUMBER IOR-KL-HY1 Muskeg River Tributary
SOURCE AGENCY:
LATITUDE 0.0 LONGITUDE 0.0
Date Processed: 2019-03-05 11:50:12 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by AViaud on 2019-02-16 00:07:05 [UTC], Updated by JHogan on 2019-02-21 22:16:43 [UTC]
Remarks:

EXPANDED CAQRating TABLE

Stage (m) — Discharge (m^3/s)

Stage (m)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
98.40	0.000*	0.001	0.002	0.002	0.003	0.004	0.005	0.006	0.006	0.007	0.01
98.50	0.008	0.009	0.009	0.010	0.011	0.012	0.013	0.013	0.014	0.015	0.01
98.60	0.016	0.017	0.017	0.018	0.019	0.020	0.021	0.021	0.022	0.023	0.01
98.70	0.024	0.024	0.025	0.026	0.027	0.028	0.028	0.029	0.030*	0.031	0.01
98.80	0.032	0.033	0.034	0.036	0.037	0.038	0.040	0.041	0.043	0.044	0.01
98.90	0.046	0.047	0.049	0.051	0.052	0.054	0.056	0.058	0.060	0.062	0.02
99.00	0.065	0.067	0.069	0.072	0.074	0.077	0.080	0.082	0.085	0.088	0.03
99.10	0.091	0.095	0.098	0.101	0.105	0.109	0.113	0.116	0.121	0.125	0.04
99.20	0.129	0.134	0.139	0.143	0.149	0.154	0.159	0.165	0.171	0.177	0.05

```
     99.30       0.183      0.189      0.196      0.203
0.210  0.218      0.225      0.233      0.241      0.250
0.08
     99.40       0.259      0.268      0.277      0.287
0.297  0.308      0.318      0.330      0.341      0.353
0.11

     99.50       0.366      0.379      0.392      0.406
0.420  0.435      0.450*
```

"*" indicates a rating descriptor point

```
  ID             Starting Date                Ending Date
     Aging  Comments
  ----    ------------------------    ------------------------
     ----- ----------------------
  001 2018-08-24 17:07:15 [UTC-07:00]
0    K6 station move 200m ds of previous location
```

STATION NUMBER IOR-KL-HY1 Muskeg River Tributary
SOURCE AGENCY:
LATITUDE 49.28
LONGITUDE -123.11
Date Processed: 2019-03-05
11:57:28 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by mchiarandini on 2014-11-27 18:10:30 [UTC],
Updated by JHogan on 2019-02-27 13:50:52 [UTC]
Remarks: New location

EXPANDED CAQRating TABLE

Stage (m) — Discharge (m^3/s)

Stage (m)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
97.60				0.000	0.000	0.000	0.000	0.00			
97.70	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.00
97.80	0.001	0.001*	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.00
97.90	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.00
98.00	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.009*	0.010	0.01
98.10	0.011	0.011	0.012	0.013	0.015	0.016	0.017	0.019	0.020	0.022	0.01
98.20	0.024	0.026	0.028	0.030	0.033	0.035	0.038	0.041	0.045	0.049	0.03
98.30	0.053	0.057	0.062	0.067	0.073	0.079	0.085	0.092	0.100	0.108	0.06
98.40	0.117	0.127	0.138	0.149	0.162	0.175	0.190*	0.193	0.197	0.200	0.09
98.50	0.204	0.208	0.211	0.215							

```
0.219  0.223     0.227      0.231      0.235      0.239
0.04
     98.60       0.244      0.248      0.253      0.257
0.262  0.266     0.271      0.276      0.281      0.286
0.05
     98.70       0.291      0.296      0.302      0.307
0.313  0.318     0.324      0.330      0.336      0.342
0.06
     98.80       0.348      0.354      0.360      0.367
0.373  0.380     0.387      0.394      0.401      0.408
0.07
     98.90       0.415      0.423      0.430      0.438
0.446  0.454     0.462      0.470      0.479      0.487
0.08

     99.00       0.496      0.505      0.514      0.523
0.533  0.542     0.552      0.562      0.572      0.582
0.10
     99.10       0.592      0.603      0.614      0.625
0.636  0.647     0.659      0.670      0.682      0.694
0.11
     99.20       0.707      0.719      0.732      0.745
0.759  0.772     0.786      0.800*

"*" indicates a rating descriptor point

  ID             Starting Date                Ending Date
     Aging  Comments
  ----    ------------------------   ------------------------
     ----- ----------------------
 0001 2013-12-31 23:59:59 [UTC-07:00]  2018-08-24 00:00:10
[UTC-07:00]       0   moved station during summer field visit
```

STATION NUMBER IOR-KL-HY1 Muskeg River Tributary
SOURCE AGENCY:
LATITUDE 49.28
LONGITUDE -123.11
Date Processed: 2019-03-05
11:55:53 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)

********Shifted for 2018-05-17
12:36:01 UTC-07:00 ********

Created by mchiarandini on 2014-11-27 18:10:30 [UTC],
Updated by JHogan on 2019-02-27 13:50:52 [UTC]
Remarks: New location

EXPANDED CAQRating TABLE

Stage (m)   Discharge (m^3/s)

Stage (m)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
98.30			0.000	0.000	0.000	0.000	0.000	0.000	0.00		
98.40	0.000	0.001	0.001	0.001	0.001	0.001	0.001*	0.001	0.001	0.001	0.00
98.50	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.00
98.60	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.00
98.70	0.006	0.006	0.007	0.007	0.008	0.008	0.009	0.010	0.011	0.011	0.01
98.80	0.012	0.013	0.015	0.016	0.017	0.019	0.020	0.022	0.024	0.026	0.02
98.90	0.028	0.030	0.033	0.035	0.038	0.041	0.045	0.049	0.053	0.057	0.03
99.00	0.062	0.074	0.087	0.104	0.124	0.147	0.175	0.194	0.201	0.209	0.16

```
    99.10      0.218      0.226      0.235      0.244
0.254  0.264      0.274      0.285      0.296      0.307
0.10
    99.20      0.319      0.332      0.345      0.358
0.372  0.387      0.402      0.418*     0.434      0.451
0.15
    99.30      0.469      0.487      0.506      0.526
0.546  0.568      0.590      0.613      0.637      0.661
0.22
    99.40      0.687      0.714      0.742      0.771
```

"*" indicates a rating descriptor point

```
  ID             Starting Date                Ending Date
     Aging  Comments
  ----     -----------------------   -----------------------
     ----- ---------------------
 0001 2013-12-31 23:59:59 [UTC-07:00]  2018-08-24 00:00:10
[UTC-07:00]       0   moved station during summer field visit
```

STATION NUMBER IOR-KL-HY2 Firebag River Tributary
SOURCE AGENCY:
LATITUDE 0.0 LONGITUDE 0.0
Date Processed: 2019-03-05 12:20:35 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by JHogan on 2019-02-14 23:04:36 [UTC], Updated by JHogan on 2019-03-05 19:20:24 [UTC]
Remarks:

EXPANDED CAQRating TABLE

Stage (m) Discharge (m^3/s)

Stage	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
99.10	0.000*	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004		0.01
99.20	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.01
99.30	0.010	0.010*	0.012	0.015	0.018	0.022	0.027	0.032	0.039	0.048	0.05
99.40	0.058	0.071	0.086	0.104	0.127	0.154	0.188	0.229	0.279	0.340*	

"*" indicates a rating descriptor point

ID	Starting Date	Ending Date	Aging	Comments
001	2018-05-15 00:00:00 [UTC-07:00]		0	

STATION NUMBER IOR-KL-HY2 Firebag River Tributary
SOURCE AGENCY:
LATITUDE 0.0 LONGITUDE
0.0
Date Processed: 2019-03-05
12:13:10 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by JHogan on 2016-12-14 22:28:29 [UTC],
Updated by JHogan on 2016-12-14 23:55:43 [UTC]
Remarks: Due to change in orifice line
location and possibly the downstream control

EXPANDED CAQRating TABLE

Stage (m) Discharge (m^3/s)
DIFF IN Q PER
.00 .01 .02 .03
.04 .05 .06 .07 .08
.09 .1 UNITS

98.10 0.000* 0.003 0.006
0.010 0.013 0.016 0.019 0.03
98.20 0.023 0.026 0.029 0.032
0.035 0.039 0.042 0.045 0.048 0.051
0.03
98.30 0.055 0.058 0.061 0.064
0.068 0.071 0.074 0.077 0.080 0.084
0.03
98.40 0.087 0.090* 0.092 0.095
0.097 0.100 0.102 0.105 0.108 0.111
0.03

98.50 0.114 0.117 0.120 0.123
0.126 0.130 0.133 0.136 0.140*

"*" indicates a rating descriptor point

ID Starting Date Ending Date
Aging Comments
---- ------------------------ ------------------------
----- ----------------------
005 2016-01-01 00:00:08 [UTC-07:00] 2018-05-16 00:00:00
[UTC-07:00] 0

STATION NUMBER IOR-KL-HY3 Firebag River
SOURCE AGENCY:
LATITUDE 0.0 LONGITUDE 0.0
Date Processed: 2019-03-05 12:40:43 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by mchiaran on 2010-11-05 22:01:35 [UTC], Updated by JHogan on 2019-03-01 18:54:02 [UTC]
Remarks: 2010 post freshet - present

Offset1: 96.50

EXPANDED CAQRating TABLE

Stage (m)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
96.50	0.800*	0.880	0.961	1.04	1.12	1.20	1.28	1.36	1.44	1.52	0.80
96.60	1.60	1.69	1.77	1.85	1.93	2.01	2.09	2.17	2.25	2.33	0.81
96.70	2.41	2.51	2.74	2.99	3.24	3.51	3.79	4.07	4.37	4.68	2.59
96.80	5.00	5.32	5.66	6.01	6.36	6.73	7.11	7.50	7.89	8.30	3.72
96.90	8.72	9.14	9.58	10.0	10.5	10.9	11.4	11.9	12.4	12.9	4.68
97.00	13.4	13.9	14.5	15.0	15.6	16.1	16.7	17.3	17.9	18.5	5.70
97.10	19.1	19.7	20.4	21.0	21.6	22.3	23.0	23.7	24.3	25.0	6.60
97.20	25.7	26.5	27.2	27.9	28.7	29.4	30.2	31.0	31.7	32.5	7.60
97.30	33.3	34.1	35.0	35.8	36.6	37.5	38.3	39.2	40.1	41.0	8.60
97.40	41.9	42.8	43.7	44.6							

Discharge (m^3/s)

```
45.5   46.5       47.4       48.4       49.4       50.3
9.40

     97.50        51.3       52.3       53.3       54.3
55.4   56.4       57.5       58.5       59.6       60.6
10.40
     97.60        61.7       62.8       63.9       65.0
66.1   67.3       68.4       69.5       70.7       71.9
11.30
     97.70        73.0       74.2       75.4       76.6
77.8   79.0       80.2       81.5       82.7       84.0
12.20
     97.80        85.2       86.5       87.8       89.1
90.4   91.7       93.0       94.4       95.7       97.0
13.20
     97.90        98.4       99.8        101        103
104     105        107        108        110        111
13.60

     98.00         112        114        115        117
118     120        121        123        124        126
15.00
     98.10         127        129        131        132
134     135        137        138        140        142
16.00
     98.20         143        145        147        148
150     152        153        155        157        158
17.00
     98.30         160        162        164        165
167     169        171        172        174        176
18.00
     98.40         178        180

"*" indicates a rating descriptor point

  ID             Starting Date                Ending Date
     Aging  Comments
 ----    -----------------------   -----------------------
     ----- ----------------------
 0002 2008-01-01 00:00:01 [MST]                               2
```

STATION NUMBER IOR-KL-HY4 Muskeg River
SOURCE AGENCY:
LATITUDE 0.0 LONGITUDE 0.0
Date Processed: 2019-03-05 12:44:05 UTC-07:00 By JHogan
Rating for Discharge (m^3/s)
Created by mchiaran on 2010-11-05 15:23:05 [UTC], Updated by JHogan on 2019-02-25 20:54:16 [UTC]
Remarks:

Offset1: 98.70

EXPANDED CAQRating TABLE

Stage (m) Discharge (m^3/s)

Stage (m)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
98.70			0.002	0.005	0.008	0.011	0.014	0.03			
98.80	0.017	0.020	0.023	0.026	0.029	0.033	0.039	0.045	0.052	0.060	0.05
98.90	0.068	0.077	0.086	0.096	0.107	0.118	0.129	0.142	0.155	0.168	0.11
99.00	0.182	0.197	0.213	0.229	0.247	0.265	0.284	0.304	0.325	0.346	0.19
99.10	0.369	0.392	0.416	0.441	0.467	0.494	0.521	0.549	0.578	0.608	0.27
99.20	0.638	0.670	0.702	0.736	0.770*	0.805	0.841	0.878	0.916	0.955	0.36
99.30	0.995	1.04	1.08	1.12	1.16	1.21	1.26	1.31	1.36	1.41	0.46
99.40	1.46	1.51	1.56	1.62	1.68	1.73	1.79	1.85	1.91	1.97	0.57
99.50	2.03	2.09	2.15	2.22	2.28	2.35	2.42	2.49	2.56	2.63	0.68
99.60	2.71	2.78	2.86	2.94							

```
3.02    3.10        3.18        3.26        3.34        3.43
0.80
     99.70          3.51        3.60        3.69        3.78
3.87    3.96        4.06        4.15        4.25        4.35
0.94
     99.80          4.45        4.55        4.66        4.76
4.87    4.97        5.08        5.19        5.30        5.42
1.08
     99.90          5.53        5.64        5.76        5.88
6.00*
```

"*" indicates a rating descriptor point

```
  ID             Starting Date               Ending Date
     Aging  Comments
  ----     ------------------------   ------------------------
     ----- ----------------------
 0001 2006-01-01 00:00:01 [MST]                              2
```

APPENDIX III

2017 and 2018 Quality Control Sample Results for Water and Sediment Quality Monitoring

Table III-1 2017 and 2018 Water Quality Program Quality Control Results – Field Blanks

Parameter	Unit	Detection Limit	Field Blank				
			WAC-1	NNL-1	NNL-1	NNL-1	WAC-1
			25-Oct-17	6-Mar-18	28-May-18	2-Sep-18	16-Oct-18
Conventional Parameters							
pH[(a,b)]	-	-	5.6	6.0	5.2	5.4	5.0
Specific conductivity	µS/cm	2	<2	<2	<2	<2	<2
Hardness, as $CaCO_3$	mg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total alkalinity, as $CaCO_3$	mg/L	1	<1	1	<1	<1	<1
Total dissolved solids	mg/L	10	<10	<10	<10[(b)]	<10	<10
Total suspended solids	mg/L	1	<1	<1	<1	<1	<1
Total organic carbon	mg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dissolved organic carbon	mg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Colour	TCU	2	<40	<2	<2[(b)]	<2	3
Major Ions							
Bicarbonate, as $CaCO_3$	mg/L	1	<1	1	<1	<1	<1
Calcium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Carbonate, as $CaCO_3$	mg/L	1	<1	<1	<1	<1	<1
Chloride	mg/L	1	<1	<1	<1	<1	<1
Magnesium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sodium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulphate	mg/L	1	<1	<1	<1	<1	<1
Sulphide	mg/L	0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019
Nutrients and Biological Indicators							
Nitrate	mg-N/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate + nitrite	mg-N/L	0.014	<0.014	<0.014	<0.014	<0.014	<0.014
Nitrite	mg-N/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrogen - ammonia	mg-N/L	0.015	<0.015	<0.015	<0.015	0.055	<0.015
Nitrogen - Kjeldahl	mg-N/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorus, total	mg-P/L	0.001 or 0.005	<0.001	<0.001	<0.005	<0.001	0.0011
Phosphorus, dissolved	mg-P/L	0.001	**0.008**	0.003	<0.001	<0.001	<0.001
Biochemical oxygen demand	mg/L	2	<2	<2	3	<2	<2
General Organics							
Naphthenic acids	mg/L	1	<1	<1	<1	<1	<1
Phenol	mg/L	0.002	<0.002	<0.002	<0.002	<0.002	0.004
Total recoverable hydrocarbons	mg/L	2	<2	<2	<2	<2	<2
Metals (Total)							
Aluminum	µg/L	0.5	<0.5	1.1	1.7	**2.9**	0.8
Antimony	µg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Arsenic	µg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Barium	µg/L	0.02	<0.02	0.02	<0.02	<0.02	<0.02
Beryllium	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	10	<10	<10	<10	<10	<10
Cadmium	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	0.1	<0.1	<0.1	0.2	<0.1	<0.1
Cobalt	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	µg/L	0.05	0.11	<0.05	<0.05	<0.05	<0.05
Iron	µg/L	1	3	<1	<1	<1	<1
Lead	µg/L	0.005	<0.005	0.008	<0.005	<0.005	<0.005
Lithium	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Manganese	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	µg/L	0.00008	0.00015	0.00018[(b)]	0.00019	0.00014	0.00012
Methyl Mercury	µg/L	0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Molybdenum	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	µg/L	0.02	<0.02	0.04	0.02	<0.02	<0.02
Selenium	µg/L	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Silver	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	µg/L	0.05	<0.05	<0.05	<0.05	0.08	<0.05
Thallium	µg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	µg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium	µg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	µg/L	0.1	<0.1	0.2	<0.1	<0.1	<0.1
Metals (Dissolved)							
Aluminum	µg/L	0.5	<0.5	<0.5	0.6	<0.5	0.6
Antimony	µg/L	0.02	<0.02	<0.02	0.03	<0.02	<0.02
Arsenic	µg/L	0.02	<0.02	<0.02	<0.02	<0.02	0.05
Barium	µg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Beryllium	µg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	µg/L	10	<10	<10	<10	<10	<10
Cadmium	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	µg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table III-1 2017 and 2018 Water Quality Program Quality Control Results – Field Blanks

Parameter	Unit	Detection Limit	Field Blank				
			WAC-1	NNL-1	NNL-1	NNL-1	WAC-1
			25-Oct-17	6-Mar-18	28-May-18	2-Sep-18	16-Oct-18
Cobalt	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron	µg/L	1	<1	<1	<1	<1	<1
Lead	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lithium	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Manganese	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Mercury	µg/L	0.00011	<0.00011[b]	<0.00011[b]	0.00011	<0.00011	<0.00011
Molybdenum	µg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	µg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Selenium	µg/L	0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Silver	µg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	µg/L	0.05	0.10	<0.05	<0.05	<0.05	<0.05
Thallium	µg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	µg/L	0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Uranium	µg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium	µg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zinc	µg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Target PAHs and Alkylated PAHs							
Acenaphthene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted acenaphthene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Acenaphthylene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Dibenzo(a,h)anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(a)anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(c)phenanthrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Biphenyl	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted biphenyl	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted biphenyl	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Chrysene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted benzo(a)anthracene/chrysene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted benzo(a)anthracene/chrysene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted benzo(a)anthracene/chrysene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C4 substituted benzo(a)anthracene/chrysene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Dibenzothiophene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted dibenzothiophene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted dibenzothiophene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted dibenzothiophene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C4 substituted dibenzothiophene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Fluoranthene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(b&j)fluoranthene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(k)fluoranthene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Indeno(1,2,3-cd)fluoranthene	ug/L	0.005	-	<0.005	<0.005	<0.005	-
Fluorene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted fluorene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted fluorene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted fluorene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Naphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
1-Methylnaphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
2-Methylnaphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted naphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted naphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted naphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C4 substituted naphthalene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Perylene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(g,h,i)perylene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Phenanthrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted phenanthrene/anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted phenanthrene/anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted phenanthrene/anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C4 substituted phenanthrene/anthracene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C1 substituted fluoranthene/pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C2 substituted fluoranthene/pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C3 substituted fluoranthene/pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
C4 substituted fluoranthene/pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Indeno(1,2,3-cd)pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Benzo(a)pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-

Table III-1 2017 and 2018 Water Quality Program Quality Control Results – Field Blanks

Parameter	Unit	Detection Limit	Field Blank				
			WAC-1	NNL-1	NNL-1	NNL-1	WAC-1
			25-Oct-17	6-Mar-18	28-May-18	2-Sep-18	16-Oct-18
Benzo(e)pyrene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Retene	µg/L	0.005	-	<0.005	<0.005	<0.005	-
PANHs							
Acridine	µg/L	0.005	-	<0.005	<0.005	<0.005	-
Quinoline	µg/L	0.005	-	<0.005	<0.005	<0.005	-

(a) pH was excluded from the assessment.

(b) Parameter was analysed past the recommended hold time.

Note: Notable results are in **bold**.

\- = no data or not applicable; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

Table III-2 2017 and 2018 Water Quality Program Quality Control Results – Duplicate Samples

Parameter	Unit	Duplicate Samples at Station MR-2				Duplicate Samples at Station WAC-1				Duplicate Samples at Station MR-2				Duplicate Samples at Station WAC-1				Duplicate Samples at Station WAC-1			
		Detection Limit	Sample 1 24-Oct-17	Sample 2 24-Oct-17	Relative Percent Difference[a]	Detection Limit	Sample 1 10-Mar-18	Sample 2 10-Mar-18	Relative Percent Difference[a]	Detection Limit	Sample 1 15-May-18	Sample 2 15-May-18	Relative Percent Difference[a]	Detection Limit	Sample 1 21-Aug-18	Sample 2 21-Aug-18	Relative Percent Difference[a]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[a]
Conventional Parameters																					
pH[b,c]	-	-	8.1	8.1	-	-	8.0	8.0	-	-	7.9	8.1	-	-	8.1	8.1	-	-	7.8	7.8	-
Specific conductivity	µS/cm	2	340	340	0%	2	570	580	2%	2	220	220	0%	2	500	500	0%	2	310	310	0%
Hardness, as $CaCO_3$	mg/L	0.5	190	190	0%	0.5	300	310	3%	0.5	110	120	9%	0.5	280	290	4%	0.5	150	150	0%
Total alkalinity, as $CaCO_3$	mg/L	1	180	180	0%	1	290	280	4%	1	100	110	10%	1	260	260	0%	1	140	140	0%
Total dissolved solids	mg/L	10	220	140	**44%**	10	320	320	0%	10	290	130	**76%**	10	300	270	11%	10	190	190	0%
Total suspended solids	mg/L	1	12	10	**21%**	1	2	1	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
Total organic carbon	mg/L	0.5	20	21	5%	0.5	11	11	0%	0.5	19	19	0%	0.5	18	18	0%	1	18	17	6%
Dissolved organic carbon	mg/L	0.5	20	21	5%	0.5	9.4	9.8	4%	0.5	19	19	0%	1	17	17	0%	1	21	20	5%
Colour	TCU	2	52	44	17%	2	21	19	10%	2	65	63	3%	2	17	17	0%	2	46	49	6%
Major Ions																					
Bicarbonate, as $CaCO_3$	mg/L	1	220	220	0%	1	350	350	0%	1	130	130	0%	1	320	320	0%	1	170	170	0%
Calcium	mg/L	0.05	47	45	4%	0.05	84	80	5%	0.05	29	29	0%	0.05	68	68	0%	0.05	35	37	6%
Carbonate, as $CaCO_3$	mg/L	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
Chloride	mg/L	1	2	2	-	1	3	4	-	1	2	2	-	1	5	5	-	1	10	11	10%
Magnesium	mg/L	0.05	19	18	5%	0.05	28	27	4%	0.05	10	10	0%	0.05	23	22	4%	0.05	12	13	8%
Potassium	mg/L	0.05	2.1	2.0	5%	0.05	1.5	1.6	6%	0.05	1.3	1.3	0%	0.05	1.3	1.3	0%	0.05	1.0	1.0	0%
Sodium	mg/L	0.05	4.4	4.3	2%	0.05	8.7	8.7	0%	0.05	3.1	3.2	3%	0.05	8.2	8.2	0%	0.05	8.9	9.3	4%
Sulphate	mg/L	1	<1	<1	-	1	4	4	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
Sulphide	mg/L	0.0019	0.0089	0.0065	-	0.0019	<0.0019	<0.0019	-	0.0019	<0.0019	0.0033	-	0.0019	0.0080	0.0076	-	0.0019	0.0100	0.0098	2%
Nutrients and Biological Indicators																					
Nitrate	mg-N/L	0.01	<0.01	0.02	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-
Nitrate + nitrite	mg-N/L	0.014	<0.014	0.015	-	0.014	<0.014	<0.014	-	0.014	<0.014	<0.014	-	0.014	<0.014	<0.014	-	0.014	<0.014	<0.014	-
Nitrite	mg-N/L	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-
Nitrogen - ammonia	mg-N/L	0.015	0.053	0.052	-	0.015	0.360	0.350	3%	0.015	<0.015	<0.015	-	0.015	0.023	0.020	-	0.015	<0.015	<0.015	-
Nitrogen - Kjeldahl	mg-N/L	0.05	1.00	1.20	18%	0.05	0.69	0.75	8%	0.05	0.65	0.58	11%	0.05	0.57	0.55	4%	0.05	0.66	0.64	3%
Phosphorus, total	mg-P/L	0.001	0.110	0.110	0%	0.001	0.015	0.022	**38%**	0.001	0.011	0.012	9%	0.001	0.015	0.016	6%	0.001	0.011	0.011	0%
Phosphorus, dissolved	mg-P/L	0.001	0.022	0.020	10%	0.001	<0.001	<0.001	-	0.001	0.007	0.006	**23%**	0.001	0.010	0.009	3%	0.001	0.004	0.006	-
Biochemical oxygen demand	mg/L	2	<2	<2	-	2	<2	2	-	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-
General Organics																					
Naphthenic acids	mg/L	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-	1	<1	<1	-
Phenol	mg/L	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	0.005	0.005	-	0.002	<0.002	<0.002	-
Total recoverable hydrocarbons	mg/L	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-
Metals (Total)																					
Aluminum	µg/L	3	100	140	**33%**	0.5	4.3	5.0	15%	3	9	9	-	3	7	9	-	3	8	6	-
Antimony	µg/L	0.02	0.05	0.04	-	0.02	<0.02	<0.02	-	0.02	0.03	0.04	-	0.02	<0.02	<0.02	-	0.02	<0.02	<0.02	-
Arsenic	µg/L	0.02	0.34	0.38	11%	0.02	0.13	0.13	0%	0.02	0.29	0.32	10%	0.02	0.26	0.26	0%	0.02	0.23	0.22	4%
Barium	µg/L	0.05	30	31	3%	0.02	65	65	0%	0.05	20	22	10%	0.05	42	44	5%	0.05	21	21	0%
Beryllium	µg/L	0.01	<0.01	0.02	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-
Boron	µg/L	10	<10	<10	-	10	43	46	-	10	13	14	-	10	33	33	-	10	16	17	-
Cadmium	µg/L	0.005	0.008	0.010	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-
Chromium	µg/L	0.1	0.2	0.2	-	0.1	0.1	<0.1	-	0.1	<0.1	<0.1	-	0.1	<0.1	0.2	-	0.1	<0.1	<0.1	-
Cobalt	µg/L	0.01	0.21	0.24	13%	0.005	0.380	0.380	0%	0.01	0.06	0.06	7%	0.01	0.17	0.19	11%	0.01	0.08	0.08	1%
Copper	µg/L	0.1	0.3	0.4	-	0.05	0.10	<0.05	-	0.1	0.2	0.2	-	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-
Iron	µg/L	5	1,400	1,500	7%	1	1,300	1,300	0%	5	150	160	6%	5	350	370	6%	1	320	320	0%
Lead	µg/L	0.02	0.10	0.12	-	0.005	0.007	0.006	-	0.02	<0.02	<0.02	-	0.02	<0.02	0.08	-	0.02	<0.02	<0.02	-
Lithium	µg/L	0.5	4.9	4.8	2%	0.5	8.9	9.3	4%	0.5	3.7	3.9	5%	0.5	8.9	9.1	2%	0.5	8.3	8.2	1%
Manganese	µg/L	0.1	140	150	7%	0.05	690	720	4%	0.1	14	15	7%	0.1	200	210	5%	0.1	63	61	3%
Mercury	µg/L	0.00008	0.00075	0.00071	6%	0.00008	0.00034	0.00037	-	0.00008	0.00094	0.00087	8%	0.00008	0.00068	0.00068	0%	0.00008	0.00047	0.00048	2%
Methyl Mercury	µg/L	0.00008	0.00013	0.00012	-	0.00008	0.00012	0.00012	-	0.00008	0.00010	0.00009	-	0.00008	0.00012	0.00012	-	0.00008	<0.00008	<0.00008	-
Molybdenum	µg/L	0.05	0.10	0.10	-	0.05	<0.05	<0.05	-	0.05	0.18	0.19	-	0.05	<0.05	<0.05	-	0.05	<0.05	<0.05	-
Nickel	µg/L	0.1	0.6	0.7	15%	0.02	0.23	0.19	19%	0.1	0.6	0.6	0%	0.1	0.3	0.4	-	0.1	0.3	0.3	-
Selenium	µg/L	0.04	<0.04	0.05	-	0.04	<0.04	<0.04	-	0.04	<0.04	0.05	-	0.04	<0.04	<0.04	-	0.04	<0.04	<0.04	-
Silver	µg/L	0.01	<0.01	<0.01	-	0.005	<0.005	<0.005	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-
Strontium	µg/L	0.05	86	88	2%	0.05	130	130	0%	0.05	60	62	3%	0.05	130	130	0%	0.05	81	80	1%
Thallium	µg/L	0.002	<0.002	0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-
Titanium	µg/L	2	2	3	-	0.5	<0.5	<0.5	-	2	<2	<2	-	2	<2	<2	-	2	<2	<2	-
Uranium	µg/L	0.005	0.087	0.097	11%	0.002	0.150	0.150	0%	0.005	0.033	0.033	0%	0.005	0.130	0.130	0%	0.005	0.019	0.021	-
Vanadium	µg/L	0.2	0.3	0.4	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-
Zinc	µg/L	1	3	3	-	0.1	2	1	**22%**	1	1	2	-	1	<1	1	-	1	<1	1	-

Table III-2 2017 and 2018 Water Quality Program Quality Control Results – Duplicate Samples

Parameter	Unit	Duplicate Samples at Station MR-2				Duplicate Samples at Station WAC-1				Duplicate Samples at Station MR-2				Duplicate Samples at Station WAC-1				Duplicate Samples at Station WAC-1			
		Detection Limit	Sample 1 24-Oct-17	Sample 2 24-Oct-17	Relative Percent Difference[a]	Detection Limit	Sample 1 10-Mar-18	Sample 2 10-Mar-18	Relative Percent Difference[a]	Detection Limit	Sample 1 15-May-18	Sample 2 15-May-18	Relative Percent Difference[a]	Detection Limit	Sample 1 21-Aug-18	Sample 2 21-Aug-18	Relative Percent Difference[a]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[a]
Metals (Dissolved)																					
Aluminum	µg/L	0.5	4.1	3.3	**22%**	0.5	1.1	1.1	-	0.5	3.6	3.8	5%	0.5	9.8	5.3	**60%**	0.5	2.8	2.6	7%
Antimony	µg/L	0.02	0.04	0.03	-	0.02	<0.02	<0.02	-	0.02	0.03	0.03	-	0.02	0.06	0.04	-	0.02	<0.02	0.02	-
Arsenic	µg/L	0.02	0.27	0.26	4%	0.02	0.10	0.11	-	0.02	0.28	0.30	7%	0.02	0.29	0.27	7%	0.02	0.20	0.22	10%
Barium	µg/L	0.02	29	28	4%	0.02	62	62	0%	0.02	20	21	5%	0.02	46	45	2%	0.02	22	23	4%
Beryllium	µg/L	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-	0.01	<0.01	<0.01	-
Boron	µg/L	10	<10	<10	-	10	40	41	-	10	14	14	-	10	37	36	-	10	16	18	-
Cadmium	µg/L	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-
Chromium	µg/L	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-
Cobalt	µg/L	0.005	0.130	0.130	0%	0.005	0.370	0.360	3%	0.005	0.045	0.042	7%	0.005	0.160	0.170	6%	0.005	0.060	0.063	5%
Copper	µg/L	0.05	<0.05	<0.05	-	0.05	<0.05	<0.05	-	0.05	0.13	0.12	-	0.05	<0.05	<0.05	-	0.05	<0.05	0.06	-
Iron	µg/L	1	400	400	0%	1	52	59	13%	1	83	82	1%	1	100	100	0%	1	170	180	6%
Lead	µg/L	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	0.006	<0.005	-	0.005	<0.005	0.005	-
Lithium	µg/L	0.5	5.3	5.3	0%	0.5	9.2	9.2	0%	0.5	3.5	3.6	3%	0.5	9.3	9.1	2%	0.5	8.1	8.6	6%
Manganese	µg/L	0.05	120	110	9%	0.05	720	700	3%	0.05	5.3	3.4	**44%**	0.05	88	95	8%	0.05	31	31	0%
Mercury	µg/L	0.00011	0.00027[c]	0.00032[c]	-	0.00011	0.00014[c]	0.00016[c]	-	0.00011	0.00052	0.00043	-	0.00011	0.00034[c]	0.00034[c]	-	0.00011	0.00039	0.00037	-
Molybdenum	µg/L	0.05	0.09	0.09	-	0.05	<0.05	<0.05	-	0.05	0.18	0.18	-	0.05	<0.05	<0.05	-	0.05	0.06	0.10	-
Nickel	µg/L	0.02	0.48	0.44	9%	0.02	0.20	0.18	11%	0.02	0.51	0.54	6%	0.02	0.32	0.30	6%	0.02	0.28	0.26	7%
Selenium	µg/L	0.04	<0.04	<0.04	-	0.04	<0.04	<0.04	-	0.04	0.04	0.05	-	0.04	<0.04	<0.04	-	0.04	0.04	<0.04	-
Silver	µg/L	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-
Strontium	µg/L	0.05	91	86	6%	0.05	120	120	0%	0.05	60	62	3%	0.05	150	140	7%	0.05	82	85	4%
Thallium	µg/L	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-	0.002	<0.002	<0.002	-
Titanium	µg/L	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-
Uranium	µg/L	0.002	0.083	0.085	2%	0.002	0.160	0.150	6%	0.002	0.029	0.033	13%	0.002	0.140	0.140	0%	0.002	0.020	0.023	14%
Vanadium	µg/L	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-
Zinc	µg/L	0.1	0.5	0.5	-	0.1	0.9	1.3	**35%**	0.1	1.0	1.0	4%	0.1	0.2	0.4	-	0.1	0.6	0.6	13%

(a) Relative percent difference was calculated using the following formula: [(maximum concentration - minimum concentration)/average concentration] x 100. Relative percent difference was calculated when reported concentrations in both duplicate samples were >5 times the detection limit.

(b) pH was excluded from the QC assessment.

(c) Parameter was analyzed past the recommended hold time.

Note: Notable results are in **bold**.

- = not applicable or the relative percent difference was not calculated because the concentration in one or both samples was less than five times the detection limit; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; QC = quality control.

Table III-3 2017 and 2018 Sediment Quality Program Quality Control Results – Split Sample

Parameter	Unit [dry wt.]	Split Samples at Station WAC-1				Split Samples at Station NNL-1				Split Samples at Station WAC-1-A[(a)]				Split Samples at Station WAC-1			
		Detection Limit	Sample 1 25-Oct-17	Sample 2 25-Oct-17	Relative Percent Difference[(b)]	Detection Limit	Sample 1 2-Sep-18	Sample 2 2-Sep-18	Relative Percent Difference[(b)]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[(b)]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[(b)]
Particle Size																	
Sand content	%	2	94	95	1%	2	62	57	8%	-	-	-	-	2	95	94	1%
Silt content	%	2	3.7	3	-	2	27	29	7%	-	-	-	-	2	2	4	-
Clay content	%	2	2	2	-	2	11	14	24%	-	-	-	-	2	3	<2	-
Moisture content	%	0.3	32	29	10%	0.3	26	32	21%	0.3	33	33	0%	0.3	31	32	3%
Carbon Content																	
Total inorganic carbon	%	0.05	0.19	1.2	-	0.05	0.89	1.7	**63%**	-	-	-	-	0.05	<0.05	<0.05	-
Total organic carbon	%	0.05	1.2	1.3	8%	0.05	2.4	2.0	18%	-	-	-	-	0.05	1.8	1.2	**40%**
Total carbon	%	0.05	1.4	2.5	**56%**	0.05	3.3	3.7	11%	-	-	-	-	0.05	1.1	1.0	10%
Organics																	
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	10	<10	<10	-	10	<10	<10	-	10	<10	<10	-	10	<10	<10	-
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	10	13	16	-	10	300	480	**46%**	10	<10	<10	-	10	<10	<10	-
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	50	140	150	-	50	2,600	4,000	**42%**	50	140	130	-	50	100	130	-
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	50	<50	57	-	50	1,200	2,000	**50%**	50	70	73	-	50	<50	59	-
Total petroleum hydrocarbons	mg/kg	50	<50	<50	-	1,000 or 500	7,000	3,000	**80%**	-	-	-	-	50	130	90	-
Metals (Total)																	
Aluminum	mg/kg	10	730	760	4%	10	3,000	2,600	14%	-	-	-	-	10	820	790	4%
Antimony	mg/kg	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	-	-	-	-	0.5	<0.5	<0.5	-
Arsenic	mg/kg	1	<1	<1	-	1	1	2	-	-	-	-	-	1	<1	<1	-
Barium	mg/kg	1	19	19	0%	1	29	34	16%	-	-	-	-	1	19	19	0%
Beryllium	mg/kg	0.4	<0.4	<0.4	-	0.4	<0.4	<0.4	-	-	-	-	-	0.4	<0.4	<0.4	-
Boron	mg/kg	2	<2	<2	-	2	5	4	-	-	-	-	-	2	<2	<2	-
Cadmium	mg/kg	0.05	<0.05	<0.05	-	0.05	<0.05	<0.05	-	-	-	-	-	0.05	<0.05	<0.05	-
Calcium	mg/kg	50	1,600	1,300	**21%**	50	39,000	38,000	3%	-	-	-	-	50	1,900	1,900	0%
Chromium	mg/kg	1	1	1	-	1	8	10	17%	-	-	-	-	1	1	1	-
Cobalt	mg/kg	0.5	0.7	0.7	-	0.5	2.7	3.4	23%	-	-	-	-	0.5	0.8	0.6	-
Copper	mg/kg	1	<1	<1	-	1	4	5	-	-	-	-	-	1	<1	<1	-
Iron	mg/kg	10	2,000	2,000	0%	10	7,000	7,000	0%	-	-	-	-	10	2,600	2,400	8%
Lead	mg/kg	0.5	0.6	0.6	-	0.5	3.3	4.0	19%	-	-	-	-	0.5	0.6	0.7	-
Lithium	mg/kg	10	<10	<10	-	10	<10	<10	-	-	-	-	-	10	<10	<10	-
Magnesium	mg/kg	20	380	300	**24%**	20	11,000	10,000	10%	-	-	-	-	20	370	350	6%
Manganese	mg/kg	10	150	150	0%	10	140	140	0%	-	-	-	-	10	130	130	0%
Mercury	mg/kg	0.05	<0.05	<0.05	-	0.05	<0.05	0.05	-	-	-	-	-	0.05	0.05	0.06	-
Molybdenum	mg/kg	0.4	<0.4	<0.4	-	0.4	0.6	0.8	-	-	-	-	-	0.4	<0.4	<0.4	-
Nickel	mg/kg	1	<1	<1	-	1	9	11	23%	-	-	-	-	1	1	<1	-
Potassium	mg/kg	25	66	61	-	25	600	590	2%	-	-	-	-	25	37	62	-
Selenium	mg/kg	0.5	<0.5	<0.5	-	0.5	<0.5	<0.5	-	-	-	-	-	0.5	<0.5	<0.5	-
Silver	mg/kg	0.2	<0.2	<0.2	-	0.2	<0.2	<0.2	-	-	-	-	-	0.2	<0.2	<0.2	-
Sodium	mg/kg	50	<50	<50	-	50	56	58	-	-	-	-	-	50	<50	<50	-
Strontium	mg/kg	10	<10	<10	-	10	27	25	-	-	-	-	-	10	<10	<10	-
Thallium	mg/kg	0.1	<0.1	<0.1	-	0.1	<0.1	<0.1	-	-	-	-	-	0.1	<0.1	<0.1	-
Titanium	mg/kg	1	12	14	15%	1	56	67	18%	-	-	-	-	1	14	13	7%
Uranium	mg/kg	0.2	<0.2	<0.2	-	0.2	0.5	0.6	-	-	-	-	-	0.2	<0.2	<0.2	-
Vanadium	mg/kg	1	2	2	-	1	11	13	17%	-	-	-	-	1	2	2	-
Zinc	mg/kg	10	<10	<10	-	10	11	15	-	-	-	-	-	10	<10	<10	-
Target PAHs and Alkylated PAHs																	
Acenaphthene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
C1 substituted acenaphthene	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-

Table III-3 2017 and 2018 Sediment Quality Program Quality Control Results – Split Sample

Parameter	Unit [dry wt.]	Split Samples at Station WAC-1				Split Samples at Station NNL-1				Split Samples at Station WAC-1-A[a]				Split Samples at Station WAC-1			
		Detection Limit	Sample 1 25-Oct-17	Sample 2 25-Oct-17	Relative Percent Difference[b]	Detection Limit	Sample 1 2-Sep-18	Sample 2 2-Sep-18	Relative Percent Difference[b]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[b]	Detection Limit	Sample 1 16-Oct-18	Sample 2 16-Oct-18	Relative Percent Difference[b]
Acenaphthylene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
Anthracene	mg/kg	0.0005	0.0007	<0.0005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	0.0013	0.0015	-
Dibenzo(a,h)anthracene	mg/kg	0.001	<0.001	<0.001	-	0.01	0.01	0.02	-	-	-	-	-	0.001	<0.001	<0.001	-
Benzo(a)anthracene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.010	0.014	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
Benzo(c)phenanthrene	mg/kg	0.005	<0.005	<0.005	-	0.05	<0.05	<0.05	-	-	-	-	-	0.005	<0.005	<0.005	-
C1 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.380	0.490	25%	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted benzo(bjk)fluoranthene/benzo(a)pyrene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.460	0.730	45%	-	-	-	-	0.005	0.009	0.024	-
Biphenyl	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-
C1 substituted biphenyl	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted biphenyl	mg/kg	0.005	<0.005	<0.005	-	0.005	0.025	0.043	-	-	-	-	-	0.005	<0.005	<0.005	-
Chrysene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.008	<0.005	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
C1 substituted benzo(a)anthracene/chrysene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.380	0.590	43%	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted benzo(a)anthracene/chrysene	mg/kg	0.005	0.008	0.005	-	0.005	1.9	2.9	42%	-	-	-	-	0.005	0.013	0.024	-
C3 substituted benzo(a)anthracene/chrysene	mg/kg	0.005	<0.005	<0.005	-	0.005	1.1	1.7	43%	-	-	-	-	0.005	0.012	0.037	-
C4 substituted benzo(a)anthracene/chrysene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.320	0.530	49%	-	-	-	-	0.005	<0.005	0.011	-
Dibenzothiophene	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-
C1 substituted dibenzothiophene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.014	0.014	-	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted dibenzothiophene	mg/kg	0.005	0.011	<0.005	-	0.005	0.600	0.750	22%	-	-	-	-	0.005	0.011	0.025	-
C3 substituted dibenzothiophene	mg/kg	0.005	<0.005	<0.005	-	0.005	1.0	1.3	27%	-	-	-	-	0.005	0.011	0.013	-
C4 substituted dibenzothiophene	mg/kg	0.005	0.015	<0.005	-	0.005	1.8	2.2	20%	-	-	-	-	0.005	<0.005	<0.005	-
Fluoranthene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.007	0.009	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
Benzo(b&j)fluoranthene	mg/kg	0.0005	0.0007	0.0007	-	0.005	0.045	0.057	24%	-	-	-	-	0.0005	0.0015	0.0018	-
Benzo(k)fluoranthene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.007	0.009	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
Fluorene	mg/kg	0.0005	0.0025	0.0021	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
C1 substituted fluorene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.016	0.030	-	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted fluorene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.099	0.130	27%	-	-	-	-	0.005	<0.005	<0.005	-
C3 substituted fluorene	mg/kg	0.005	<0.005	0.009	-	0.005	0.500	0.700	33%	-	-	-	-	0.005	<0.005	0.034	-
Naphthalene	mg/kg	0.0005	0.0010	0.0010	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	<0.0005	<0.0005	-
1-Methylnaphthalene	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-
2-Methylnaphthalene	mg/kg	0.005	<0.005	<0.005	-	0.05	<0.05	<0.05	-	-	-	-	-	0.005	<0.005	<0.005	-
C1 substituted naphthalene	mg/kg	0.005	<0.005	<0.005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted naphthalene	mg/kg	0.005	0.023	0.025	-	0.005	0.051	0.089	**54%**	-	-	-	-	0.005	0.013	0.017	-
C3 substituted naphthalene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.053	0.073	32%	-	-	-	-	0.005	<0.005	<0.005	-
C4 substituted naphthalene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.170	0.250	38%	-	-	-	-	0.005	<0.005	<0.005	-
Perylene	mg/kg	0.005	<0.005	<0.005	-	0.05	0.06	0.08	-	-	-	-	-	0.005	<0.005	<0.005	-
Benzo(g,h,i)perylene	mg/kg	0.001	<0.001	<0.001	-	0.01	0.03	0.04	-	-	-	-	-	0.001	<0.001	<0.001	-
Phenanthrene	mg/kg	0.0005	0.0009	<0.0005	-	0.005	<0.005	<0.005	-	-	-	-	-	0.0005	<0.0005	0.0007	-
C1 substituted phenanthrene/anthracene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.040	0.054	30%	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted phenanthrene/anthracene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.220	0.320	37%	-	-	-	-	0.005	<0.005	<0.005	-
C3 substituted phenanthrene/anthracene	mg/kg	0.005	0.019	0.007	-	0.005	1.2	1.4	15%	-	-	-	-	0.005	0.014	0.045	-
C4 substituted phenanthrene/anthracene	mg/kg	0.005	0.052	0.014	-	0.005	1.5	2.2	38%	-	-	-	-	0.005	0.020	0.070	-
Pyrene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.077	0.090	16%	-	-	-	-	0.0005	0.0007	0.0009	-
C1 substituted fluoranthene/pyrene	mg/kg	0.005	<0.005	<0.005	-	0.005	0.570	0.750	27%	-	-	-	-	0.005	<0.005	<0.005	-
C2 substituted fluoranthene/pyrene	mg/kg	0.005	0.011	0.0065	-	0.005	1.7	2.6	42%	-	-	-	-	0.005	0.013	0.023	-
C3 substituted fluoranthene/pyrene	mg/kg	0.005	0.011	0.008	-	0.005	4.9	7.2	38%	-	-	-	-	0.005	0.032	0.046	36%
C4 substituted fluoranthene/pyrene	mg/kg	0.005	0.010	<0.005	-	0.005	2.7	3.9	36%	-	-	-	-	0.005	0.023	0.050	-
Indeno(1,2,3-cd)pyrene	mg/kg	0.001	<0.001	<0.001	-	0.01	0.02	0.03	-	-	-	-	-	0.001	<0.001	<0.001	-
Benzo(a)pyrene	mg/kg	0.0005	<0.0005	<0.0005	-	0.005	0.029	0.041	34%	-	-	-	-	0.0005	<0.0005	<0.0005	-

Table III-3 2017 and 2018 Sediment Quality Program Quality Control Results – Split Sample

Parameter	Unit [dry wt.]	Split Samples at Station WAC-1				Split Samples at Station NNL-1				Split Samples at Station WAC-1-A[a]				Split Samples at Station WAC-1			
		Detection Limit	Sample 1	Sample 2	Relative Percent Difference[b]	Detection Limit	Sample 1	Sample 2	Relative Percent Difference[b]	Detection Limit	Sample 1	Sample 2	Relative Percent Difference[b]	Detection Limit	Sample 1	Sample 2	Relative Percent Difference[b]
			25-Oct-17	25-Oct-17			2-Sep-18	2-Sep-18			16-Oct-18	16-Oct-18			16-Oct-18	16-Oct-18	
Benzo(e)pyrene	mg/kg	0.005	<0.005	<0.005	-	0.05	0.06	0.08	-	-	-	-	-	0.005	<0.005	<0.005	-
Retene	mg/kg	0.005	0.056	0.011	-	0.005	0.017	0.026	**42%**	-	-	-	-	0.005	0.019	0.074	-
PANHs																	
Acridine	mg/kg	0.01	<0.01	<0.01	-	0.1	<0.1	<0.1	-	-	-	-	-	0.01	<0.01	<0.01	-
Quinoline	mg/kg	0.01	<0.01	<0.01	-	0.1	<0.1	<0.1	-	-	-	-	-	0.01	<0.01	<0.01	-

(a) These results were collected at the same location and time as WAC-1 during the October 2018 program, but were collected using the methonal vial method, rather than the 125 mL soil jars

(b) Relative percent difference was calculated using the following formula: [(maximum concentration - minimum concentration)/average concentration] x 100. Relative percent difference was calculated when reported concentrations in both duplicate samples were >5 times the detection limit.

Note: Notable results are in bold.

- = no data or the relative percent difference was not calculated because the concentration in one or both samples was less than five times the detection limit; dry wt. = dry weight; < = less than; mg/kg = milligrams per killogram; PAHs = polycylic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles.

APPENDIX IV

Water Quality Data from 2006 to 2018

Table IV-1: Compiled Water Quality Data from the Firebag River Wateshed, 2006 to 2018

Parameter	Unit	Firebag River Stations																					
		ET-1 29-May-06	ET-1 26-Jul-06	ET-1 4-Oct-06	ET-1 24-Apr-08	ET-1 7-Jul-08	ET-1 7-Nov-08	ET-1 20-Jul-09	ET-1 24-Mar-10	ET-1 1-Apr-11	CT-1 29-May-06	CT-1 26-Jul-06	CT-1 4-Oct-06	CT-1 7-Jul-08	CT-1 6-Nov-08	CT-1 28-Apr-10	WT-1 29-May-06	WT-1 28-Aug-06	WT-1 4-Oct-06	WT-1 24-Apr-08	WT-1 7-Jul-08	WT-1 24-Mar-10	WT-1 21-Aug-11
Field Measured																							
pH	-	7.7	-	-	-	8.1	8.3	7.3	7.1	7.4	7.4	-	-	7.4	7.6	6.6	7.4	8.4	7.8	-	7.6	7.3	7.8
Specific conductivity	µS/cm	211	-	-	-	312	291	318	294	493	177	-	-	291	280	230	406	336	490	-	480	466	451
Temperature	°C	13.6	-	-	-	15.2	1.2	16.3	0.0	0.0	11.1	-	-	14.1	0.3	0.8	11.5	16.3	4.9	-	13.6	0.1	14.6
Dissolved oxygen	mg/L	10.5	-	-	-	10.0	1.5	9.0	7.2	10.2	-	-	-	8.8	1.0	8.9	6.8	2.3	11.6	-	7.3	1.0	6.2
Conventional Parameters																							
pH	-	8.2	8.1	8.2	7.8	8.3	8.2	8.2	7.4	8.2	8.1	8.1	8.1	8.0	8.1	8.2	8.1	8.1	8.2	7.9	8.0	7.7	8.1
Specific Conductivity	µS/cm	276	310	316	322	333	318	267	420	500	234	330	364	313	306	240	526	618	643	370	530	720	580
Hardness	mg/L	147	190	173	179	198	178	139	243	279	123	197	210	185	154	127	279	394	389	205	320	509	333
Total alkalinity, as $CaCO_3$	mg/L	146	178	170	179	184	170	142	230	280	120	190	196	170	163	130	272	382	354	199	302	420	320
Total dissolved solids	mg/L	160	208	213	218	243	206	189	190	300	160	224	254	229	201	150	330	450	420	253	380	410	380
Total suspended solids	mg/L	<3.0	<3.0	<3.0	<3.0	3.0	<3.0	<3.0	6.0	1.0	<3.0	8.0	3.0	<3.0	<3.0	4.0	11	<3.0	7.0	<3.0	27	220	<1.0
Total organic carbon	mg/L	12	23	15	14	20	15	21	12	9.9	24	28	20	22	16	17	25	41	15	19	30	27	30
Dissolved organic carbon	mg/L	12	22	14	14	19	15	22	12	10	16	27	20	24	18	15	24	39	13	19	30	24	28
Colour	TCU	50	70	50	53	91	53	100	50	34	50	70	30	64	28	39	70	140	30	64	110	59	74
Major Ions																							
Calcium	mg/L	39	49	44	45	51	44	37	59	72	31	49	51	46	37	31	75	106	94	51	85	119	91
Magnesium	mg/L	12	16	15	16	18	16	11	20	25	11	18	20	17	15	12	22	32	38	19	26	33	27
Potassium	mg/L	<0.5	0.7	<0.5	1.5	<0.5	<0.5	<0.5	1.0	1.7	0.7	0.8	1.5	<0.5	0.9	2.0	2.1	2.4	2.1	3.7	0.7	2.6	1.5
Sodium	mg/L	3	2	2	1	1	2	1	2	3	3	4	4	3	3	3	7	6	4	3	4	4	4
Bicarbonate	mg/L	178	217	207	219	223	208	173	280	340	147	231	239	208	198	150	332	467	432	243	368	520	400
Carbonate	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<0.5	<0.5	<5.0	<5.0	<5.0	<5.0	<5.0	<0.5	<5.0	<5.0	<5.0	<5.0	<5.0	<0.5	<0.5
Chloride	mg/L	2	2	1	<1	1	1	<1	1	2	2	2	2	1	2	1	4	2	2	2	2	1	2
Sulphate	mg/L	3	3	1	2	2	2	1	<1	<1	3	3	2	1	1	<1	13	3	11	8	2	<1	<1
Sulphide	mg/L	0.005	0.01	0.005	0.005	0.003	0.005	0.005	0.012	<0.002	<0.003	0.008	0.005	0.014	<0.002	0.005	0.007	0.012	<0.003	0.005	0.006	0.058	<0.002
Nutrients and Biological Indicators																							
Nitrate + nitrite	mg-N/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.071	0.008	0.170	<0.1	<0.1	<0.1	<0.1	<0.1	0.006	<0.1	<0.1	<0.1	<0.1	<0.1	<0.003	0.005
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.14	0.36	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	1.5	<0.05
Total Kjeldahl nitrogen	mg-N/L	0.5	0.8	0.5	0.4	0.8	0.5	1.0	0.8	0.9	0.4	0.7	0.6	0.7	0.4	0.8	1.3	1.7	0.5	0.8	1.0	3.5	0.9
Total phosphorus	mg-P/L	0.02	0.03	0.03	0.02	0.04	0.01	0.02	0.02	0.02	0.02	0.05	0.03	0.02	0.01	0.01	0.1	0.11	0.05	0.07	0.04	0.03	0.03
Dissolved phosphorus	mg-P/L	0.014	0.035	0.023	0.013	0.020	0.009	0.013	0.011	0.010	0.013	0.024	0.018	0.014	0.009	0.012	0.026	0.059	0.025	0.047	0.016	0.015	0.011
Biochemical oxygen demand	mg/L	<2.0	3.0	<2.0	<2.0	<2.0	<2.0	5.1	<3.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<3.0	7.0	4.0	<2.0	2.0	<2.0	12	<2.0
General Organics																							
Naphthenic acids	mg/L	<1.0	<1.0	1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	<0.001	0.015	<0.001	0.007	0.007	0.005	0.007	<0.002	0.002	0.004	0.014	<0.001	0.006	0.004	<0.002	0.001	0.028	<0.001	0.008	0.007	<0.002	0.002
Total recoverable hydrocarbons	mg/L	<1.0	<1.0	<1.0	1.3	<1.0	<1.0	-	<2.0	<2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<1.0	-	<1.0	1.0	<1.0	<2.0	<2.0
Total Metals																							
Aluminum	µg/L	50	40	30	30	180	30	50	10	20	<20	30	<20	<20	<20	30	50	30	<20	<20	30	1,000	30
Antimony	µg/L	1.9	0.5	<0.4	0.5	0.4	<0.4	<0.4	0.1	<0.1	0.9	0.5	<0.4	0.5	<0.4	0.02	2	1.1	<0.4	0.7	0.5	0.04	0.04
Arsenic	µg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.16	0.1	<0.4	<0.4	0.4	<0.4	<0.4	0.18	<0.4	1.1	<0.4	<0.4	0.5	0.96	0.43
Barium	µg/L	29	37	37	32	42	27	31	41	49	33	49	57	50	30	29	63	93	87	29	62	141	60
Beryllium	µg/L	<1	<1	<1	<1	<1	<1	<1	<0.01	<0.05	<1	<1	<1	<1	<1	<0.01	<1	<1	<1	<1	<1	0.11	<0.01
Boron	µg/L	<20	<20	<20	<20	<20	<20	<20	<50	<300	60	60	50	50	30	<50	100	60	70	30	40	60	53
Cadmium	µg/L	<0.2	<0.2	<0.2	-	-	-	-	0.031	<0.03	<0.2	<0.2	<0.2	-	-	<0.005	<0.2	<0.2	<0.2	-	-	0.256	0.016
Chromium	µg/L	<0.8	<0.8	<0.8	1.5	<0.8	<0.8	<0.8	<0.1	<0.5	<0.8	<0.8	<0.8	<0.8	<0.8	<0.1	<0.8	<0.8	<0.8	1.4	<0.8	1.3	0.2
Cobalt	µg/L	0.3	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	0.083	0.07	<0.2	0.2	0.3	<0.2	<0.2	0.078	0.3	0.6	<0.2	<0.2	0.2	1.32	0.109
Copper	µg/L	<1	<1	<1	<1	<1	<1	<1	0.5	0.5	<1	<1	<1	<1	<1	0.5	<1	<1	<1	<1	<1	0.7	0.3
Iron	µg/L	280	1,000	1,000	410	1,000	340	430	1,000	1,000	200	1,000	1,000	360	120	160	1,000	1,000	210	150	470	7,000	320
Lead	µg/L	<0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.1	0.13	0.06	<0.1	<0.1	<0.1	<0.1	<0.1	0.07	<0.1	<0.1	<0.1	0.3	<0.1	1.87	0.07
Lithium	µg/L	<6	<6	<6	<6	<6	<6	<6	7	11	19	21	23	20	20	18	31	28	25	16	23	24	21
Manganese	µg/L	37	195	128	73	172	42	48	284	155	17	135	112	42	25	11	38	1,000	25	38	77	1,000	0
Mercury	µg/L	<0.0006	0.001	<0.0006	<0.0006	0.002	<0.0006	0.001	0.0015	<0.0006	<0.0006	<0.0006	0.0016	<0.0006	<0.0006	0.0007	<0.0006	0.001	<0.0006	0.0011	0.0022	0.0037	<0.0006
Methyl mercury	µg/L	0.0001	0.00007	0.0001	0.00018	<0.00003	0.00005	0.00004	<0.00003	<0.00003	0.00006	0.0001	0.00005	0.00004	<0.00003	<0.00003	0.00031	0.00032	0.00005	0.00007	0.00032	<0.00008	0.00022
Molybdenum	µg/L	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.12	0.22	<0.3	<0.1	<0.1	0.1	<0.1	<0.1	0.09	0.1	<0.1	0.2	<0.1	0.1	<0.05	0.1
Nickel	µg/L	<0.2	<0.2	1	0.7	1.7	0.8	1	0.3	0.3	<0.2	<0.2	1.5	1.4	0.9	0.4	<0.2	2.5	1.6	1	2.5	2.8	0.5
Selenium	µg/L	<0.4	<0.4	<0.4	3.6	<0.4	<0.4	<0.4	0.05	0.2	<0.4	<0.4	<0.4	<0.4	<0.4	<0.04	<0.4	<0.4	<0.4	5.1	0.4	1.4	0.04
Silver	µg/L	0.0261	0.0044	0.0062	0.1	0.049	0.24	0.085	<0.005	<0.03	0.012	0.005	0.006	0.032	0.055	<0.005	0.02	0.03	0.001	0.085	0.045	0.005	<0.005
Strontium	µg/L	60	70	80	60	60	60	50	80	110	190	290	320	250	210	160	350	380	250	150	270	340	250
Thallium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.002	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	0.004	<0.1	<0.1	<0.1	<0.1	<0.1	0.006	<0.002
Titanium	µg/L	<5	<5	<5	<5	<5	<5	<5	0.6	<3	<5	<5	<5	<5	<5	<0.5	<5	<5	<5	<5	<5	7.9	0.8
Uranium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.009	0.05	<0.1	<0.1	<0.1	<0.1	<0.1	0.02	0.2	<0.1	0.2	<0.1	<0.1	0.09	0.12
Vanadium	µg/L	<0.2	0.4	0.3	0.5	0.6	<0.2	1.34	<0.2	<1	<0.2	0.2	<0.2	0.1	<0.2	<0.2	<0.2	<0.2	0.3	0.8	0.4	4	<0.2
Zinc	µg/L	<4	<4	14	9	7	<4	5	5	2	<4	<4	8	<4	<4	8	<4	<4	13	9	<4	0.05	2
Dissolved Metals																							
Aluminum	µg/L	10	20	<10	<10	<10	<10	<10	7	6	10	<10	<10	<10	<10	4	<10	<10	<10	<10	<10	5	7
Antimony	µg/L	<0.4	0.6	0.7	0.5	0.4	<0.4	<0.4	<0.02	<0.02	0.6	0.6	0.6	0.5	<0.4	<0.02	0.8	0.8	0.6	0.5	0.5	0.04	0.03
Arsenic	µg/L	<0.4	0.5	<0.4	<0.4	<0.4	<0.4	<0.4	0.11	0.13	<0.4	0.5	<0.4	<0.4	<0.4	0.18	0.4	1.1	<0.4	<0.4	<0.4	0.73	0.39
Barium	µg/L	30	30	30	30	50	30	30	40	50	30	50	50	40	30	30	60	80	80	30	60	90	60
Beryllium	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	<0.01	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	<0.01
Boron	µg/L	16	23	14	9	50	10	18	<50	<50	52	59	36	15	34	<50	110	58	58	32	44	<50	63
Cadmium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.011	<0.005	<0.1	<0.1	<0.1	<0.1	<0.1	<0.005	<0.1	<0.1	<0.1	<0.1	<0.1	0.007	<0.005
Chromium	µg/L	4.2	0.7	1.4	<0.4	<0.4	<0.4	<0.4	<0.1	0.1	5.2	1.1	1.2	<0.4	<0.4	<0.1	1.1	1	0.9	<0.4	<0.4	0.1	0.3
Cobalt	µg/L	0.1	0.2	0.3	0.3	1	<0.1	<0.1	0.08	0.079	0.4	0.3	0.4	0.5	0.1	0.07	0.5	0.5	0.4	0.8	0.3	0.33	0.093
Copper	µg/L	2.1	<0.6	<0.6	0.7	<0.6	<0.6	<0.6	0.09	0.12	1.3	1.2	<0.6	<0.6	<0.6	0.32	1.1	<0.6	<0.6	<0.6	<0.6	0.1	0.38
Iron	µg/L	200	1,000	400	300	200	200	200	1,000	400	200	1,000	400	400	100	100	300	1,000	100	100	200	1,000	100
Lead	µg/L	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.03	0.01	0.5	<0.1	<0.1	<0.1	<0.1	0.05	<0.1	<0.1	<0.1	<0.1	<0.1	0.21	0.04
Lithium	µg/L	4	4	4	5	18	4	<3	7	9	17	19	19	4	21	21	29	23	23	17	20	24	22
Manganese	µg/L	31	180	90	64	41	34	25	270	140	17	130	110	51	25	9	36	490	33	38	44	720	5
Mercury	µg/L	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.001	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0009	<0.0006
Molybdenum	µg/L	0.3	0.2	0.1	<0.1	<0.1	<0.1	<0.1	<0.05	0.1	0.3	0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nickel	µg/L	2	<0.1	0.7	1	1.3	0.9	0.7	0.1	0.2	2.1	<0.1	0.8	1.1	0.8	0.3	<0.1	<0.1	1.4	1.3	2	0.6	1.6
Selenium	µg/L	0.6	<0.4	<0.4	0.4	<0.4	<0.4	<0.4	<0.04	<0.04	<0.4	0.4	0.4	<0.4	<0.4	<0.04	<0.4	<0.4	<0.4	<0.4	<0.4	0.06	0.04
Silver	µg/L	<0.2	0.001	0.001	-	-	-	0.0054	<0.005	<0.005	<0.2	0.0008	0.0009	-	-	<0.005	<0.2	<0.2	0.0009	-	-	<0.005	<0.005
Strontium	µg/L	50	70	60	60	240	60	60	80	100	180	270	260	60	210	170	310	330	220	160	260	310	250
Thallium	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.002	<0.002	<0.05	<0.05	<0.05	<0.05	<0.05	<0.002	<0.05	<0.05	<0.05	<0.05	<0.05	<0.002	<0.002
Titanium	µg/L	0.5	1.7	<0.3	0.4	<0.3	0.7	0.61	<0.5	<0.5	0.5	1.2	<0.3	<0.3	0.7	<0.5	0.7	1.8	0.8	0.7	<0.3	<0.5	<0.5
Uranium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.01	0.04	<0.1	<0.1	<0.1	<0.1	<0.1	0.02	0.1	<0.1	0.2	<0.1	<0.1	0.1	0.1
Vanadium	µg/L	0.3	0.9	0.6	0.1	<0.1	<0.1	0.2	<0.2	<0.2	0.3	0.8	0.5	<0.1	<0.1	<0.2	0.3	0.2	0.5	0.2	<0.1	0.3	<0.2
Zinc	µg/L	140	3	<2	5	<2	<1	<1	6	1	140	3	4	<2	<1	2	4	<2	2	9	<2	1	3

(a) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(b) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
- = not a licable or no data available; S/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; CCME = Canadian Council of Ministers of the Environment.

Table IV-1: Compiled Water Quality Data from the Firebag River Wateshed, 2006 to 2018

Parameter	Unit	Firebag River Stations																										
		FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1
		29-May-06	28-Aug-06	4-Oct-06	24-Apr-08	7-Jul-08	6-Nov-08	24-Mar-10	28-Apr-10	29-Jul-10	25-Oct-10	1-Apr-11	8-May-11	21-Aug-11	16-Oct-11	16-Mar-12	9-May-12	18-Jul-12	16-Oct-12	18-Apr-13	18-Oct-13	16-Mar-14	6-May-14	3-Sep-14	21-Oct-14	15-Mar-15	26-May-15	17-Nov-15
Field Measured																												
pH	-	7.9	7.3	8.0	-	8.4	8.1	7.0	6.9	7.6	8.2	7.5	9.0	9.0	7.8	6.6	7.0	-	-	6.9	-	7.1	7.3	8.1	-	7.1	8.0	5.6
Specific conductivity	µS/cm	104	336	142	-	183	174	203	119	377	215	214	127	166	116	213	112	172	-	117	148	227	452	206	141	212	153	396
Temperature	°C	14.2	15.8	5.7	-	17.8	0.9	0.0	4.8	20.7	0.8	0.1	6.7	18.2	3.5	0.1	9.7	19.7	-	0.0	4.4	0.0	2.5	12.1	0.6	0.1	16.4	-0.3
Dissolved oxygen	mg/L	10.2	-	14.1	-	11.4	15.8	5.3	11.5	15.3	13.8	6.7	12.1	11.3	14.1	2.1	11.2	9.2	-	11.5	11.5	3.5	13.8	11.3	14.7	4.0	11.0	14.4
Conventional Parameters																												
pH	-	8.1	8.2	8.2	7.8	8.3	8.0	7.1	7.9	8.3	8.1	8.0	8.0	8.5	8.2	7.6	7.9	8.0	8.1	7.9	7.7	7.5	7.7	8.2	8.0	7.8	8.1	8.1
Specific Conductivity	µS/cm	138	184	189	172	200	190	230	130	200	180	210	140	200	210	220	130	170	160	220	150	230	88	210	180	220	180	210
Hardness	mg/L	69	101	98	84	109	95	116	63	110	92	103	70	103	110	110	72	100	84	105	77	115	41.6	114	95.2	105	94.1	104
Total alkalinity, as $CaCO_3$	mg/L	68	101	97	90	106	97	120	65	110	89	100	69	100	110	110	65	90	80	100	72	100	41	110	88	100	87	100
Total dissolved solids	mg/L	90	120	137	129	148	133	110	70	130	140	120	90	140	140	100	96	150	120	130	120	150	68	130	160	130	100	140
Total suspended solids	mg/L	<3.0	<3.0	3.0	8.0	6.0	4.0	5.0	8.0	5.0	<1.0	3.0	10	3.0	1.0	<1.0	10	3.0	<2.5	<0.5	2.0	1.3	32	1.3	1.3	<1.0	2.4	2.1
Total organic carbon	mg/L	11	15	12	11	14	11	5.4	11	9.3	11	4.4	12	11	8.3	4.5	13	23	15	6.2	14	5.6	16	8.4	9.7	4.3	8.3	8.7
Dissolved organic carbon	mg/L	10	15	12	10	14	12	4.9	11	8.7	10	4.4	11	11	8.1	4.5	12	22	18	5.8	13	5.6	15	8.4	11	4.1	8	8.8
Colour	TCU	60	60	35	56	49	48	33	58	28	39	16	43	35	26	14	44	98	56	24	51	21	62	38	43	18	37	38
Major Ions																												
Calcium	mg/L	19	27	26	22	29	25	31	17	29	24	27	18	28	28	30	19	26	21	30	22	28.1	12.1	29.2	25.6	28.4	25.4	27.1
Magnesium	mg/L	5.4	7.9	8.0	7.1	9.1	8.0	9.6	5.2	9.0	7.6	8.1	5.5	7.7	8.5	8.9	5.4	7.3	6.7	8.8	6.6	8.31	3.78	9.16	7.58	8.8	7.43	8.79
Potassium	mg/L	<0.5	0.7	0.7	1.3	0.6	<0.5	1.2	0.83	0.5	0.55	1.0	1.0	0.61	0.89	1.1	1.3	0.41	0.45	1.1	0.53	0.948	1.19	0.823	0.664	1.05	0.925	0.852
Sodium	mg/L	3	4	3	3	4	3	4	2	3	3	3	3	3	4	4	3	3	3	4	3	3.43	1.7	3.07	3.35	3.63	3.2	4.14
Bicarbonate	mg/L	83	124	119	109	129	118	140	79	130	110	120	84	120	130	140	79	110	97	120	88	130	50	130	110	130	110	120
Carbonate	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	3.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Chloride	mg/L	2	2	1	1	1	1	2	1	2	2	1	2	1	1	2	2	1	1	<1	1	<1.0	1.3	1.1	1.4	1.4	<1.0	1.1
Sulphate	mg/L	3	2	2	2	2	2	<1	<1	<1	<1	2	<1	<1	<1	3	<1	<1	<1	3	<1	1.1	<1.0	<1.0	<1.0	2.6	<1.0	<1.0
Sulphide	mg/L	<0.003	0.008	0.004	0.005	<0.002	0.007	0.009	0.004	0.005	0.005	<0.002	0.12	<0.002	<0.002	0.012	0.005	<0.002	<0.002	<0.002	<0.002	<0.0020	<0.0020	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019
Nutrients and Biological Indicators																												
Nitrate + nitrite	mg-N/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.170	0.011	<0.003	<0.003	0.270	<0.003	0.012	0.013	0.230	<0.003	0.007	0.021	0.210	0.031	0.3	0.011	<0.010	<0.010	0.25	<0.010	0.16
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	0.11	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	<0.050	<0.050	<0.050	0.11	<0.050	<0.050
Total Kjeldahl nitrogen	mg-N/L	0.4	0.6	0.4	0.4	0.8	0.4	0.5	0.8	0.6	0.9	0.6	0.9	0.8	0.4	0.3	0.7	0.9	0.5	0.3	0.6	0.3	0.51	0.31	0.34	0.31	0.59	0.51
Total phosphorus	mg-P/L	0.05	0.08	0.07	0.12	0.08	0.05	0.03	0.05	0.03	0.03	0.07	0.08	0.06	0.03	0.06	0.09	0.12	0.06	0.07	0.05	0.073	0.086	0.04	0.048	0.054	0.062	0.031
Dissolved phosphorus	mg-P/L	0.029	0.059	0.045	0.045	0.013	0.028	0.021	0.033	0.019	0.028	0.032	0.024	0.003	0.020	0.016	0.024	0.077	0.018	0.040	0.055	0.047	0.038	0.031	0.031	0.03	0.018	0.027
Biochemical oxygen demand	mg/L	<2.0	<2.0	3.0	<2.0	2.0	<2.0	<3.0	<3.0	<2.0	<2.0	<2.0	<2.0	2.0	<2.0	<2.0	2.1	<2.0	<2.0	<2.0	<2.0	<2.0	2.4	<2.0	<2.0	<2.0	2.5	<2.0
General Organics																												
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1	<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.008	0.01	<0.001	0.007	0.004	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	0.003	0.003	<0.002	0.005	-	0.004	<0.002	0.006	0.002	0.0052	0.0036	0.002	<0.0020	0.0026	<0.0020
Total recoverable hydrocarbons	mg/L	<1.0	-	<1.0	-	<1.0	<1.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals																												
Aluminum	µg/L	60	20	30	130	40	<20	30	30	20	10	20	40	10	10	4	60	50	20	10	10	16	220	6	10	15	19	22
Antimony	µg/L	1.2	0.6	<0.4	0.4	0.5	<0.4	0.04	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.020	<0.020	<0.020	<0.020	<0.020	<0.050	<0.020
Arsenic	µg/L	<0.4	0.5	0.5	0.4	0.5	<0.4	0.28	0.27	0.46	0.22	0.24	0.34	0.48	0.32	0.218	0.399	0.713	0.325	0.311	0.284	0.268	0.364	0.441	0.275	0.274	0.364	0.25
Barium	µg/L	19	25	26	28	27	21	30	18	23	21	25	22	24	23	26	25	28	20	25	16	24.5	17	22	20.1	26.7	22.4	25.2
Beryllium	µg/L	<1	<1	<1	<1	<1	<1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	0.01	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<20	<20	<20	<20	<20	<20	<50	<50	20	<20	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<20	<20	13	<50	14
Cadmium	µg/L	<0.2	<0.2	<0.2	-	-	-	0.048	<0.005	<0.005	<0.005	0.021	0.014	<0.005	<0.005	<0.005	0.009	0.006	<0.005	<0.005	<0.005	<0.0050	0.007	<0.0050	<0.0050	<0.0050	0.009	0.018
Chromium	µg/L	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	0.1	<0.1	<0.1	<0.1	0.4	0.1	0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.10	0.23	<0.10	<0.10	0.11	<0.50	0.11
Cobalt	µg/L	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	0.061	0.066	0.133	0.041	0.043	0.094	0.068	0.031	0.026	0.101	0.108	0.072	0.052	0.046	0.038	0.187	0.059	0.039	0.0329	0.073	0.046
Copper	µg/L	<1	<1	<1	1	<1	<1	0.8	0.4	0.2	<0.05	0.4	0.2	0.1	0.1	0.3	0.2	0.1	0.1	0.2	0.1	0.241	0.321	0.092	0.116	0.222	0.5	0.197
Iron	µg/L	450	1,000	1,000	1,000	1,000	1,000	1,000	1,000	90	1,000	1,000	1,000	370	420	420	1,000	1,000	1,000	1,000	1,000	732	1,260	412	543	607	431	451
Lead	µg/L	<0.1	<0.1	<0.1	0.1	0.1	<0.1	1.04	0.07	0.04	0.01	0.16	0.06	0.03	0.06	0.01	0.07	0.03	0.04	0.04	0.02	0.035	0.169	0.011	0.042	0.0189	<0.050	0.025
Lithium	µg/L	<6	<6	<6	<6	<6	<6	4	2	5	4	4	3	4	4	4	3	3	3	4	3	3.85	1.82	3.48	3.37	3.87	3.57	4.65
Manganese	µg/L	34	34	25	109	157	24	26	40	5	10	27	71	55	18	21	92	55	35	46	17	43	70	42	24	27	94	11
Mercury	µg/L	<0.0006	<0.0006	<0.0006	0.0008	0.0011	-	<0.0006	0.0021	<0.0006	<0.002	0.0006	0.0009	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.001	0.001	0.000521	0.00463	0.00064	0.00059	0.00051	0.00113	0.00062
Methyl mercury	µg/L	0.00005	<0.00003	0.00007	<0.00003	<0.00003	0.00003	<0.00003	<0.00003	<0.00003	-	<0.00003	<0.00003	<0.00003	0.00004	<0.00008	0.00009	0.00038	<0.00008	<0.00008	0.00009	<0.00008	0.00011	<0.00008	<0.00008	<0.00008	0.00009	<0.00008
Molybdenum	µg/L	0.2	0.2	0.2	0.2	0.3	0.2	0.22	0.14	0.28	0.13	0.3	0.54	0.17	0.19	0.228	0.177	0.177	0.109	0.198	0.094	0.191	0.153	0.241	0.171	0.268	0.323	0.21
Nickel	µg/L	<0.2	0.7	0.7	0.7	1	1.3	0.6	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.3	0.4	0.3	0.1	0.3	0.206	0.489	0.158	0.193	0.224	0.27	0.186
Selenium	µg/L	<0.4	<0.4	<0.4	1.2	<0.4	<0.4	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.047	<0.04	<0.04	<0.04	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Silver	µg/L	0.009	0.038	0.003	0.002	0.053	0.13	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.007	<0.0050
Strontium	µg/L	40	60	60	50	60	50	60	30	60	50	50	40	60	50	60	40	60	40	60	40	55	25	57	47	54	53	54
Thallium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	0.002	<0.002	<0.002	<0.002	<0.0020	0.002	<0.0020	<0.0020	<0.0020	0.002	<0.0020
Titanium	µg/L	<5	<5	<5	<5	<5	<5	<0.5	0.9	<0.5	<0.5	<0.5	1.7	0.6	<0.5	<0.5	1.9	<0.5	1.3	0.7	<0.5	<0.50	5.75	0.56	<0.50	0.55	<5.0	0.63
Uranium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.05	0.03	0.06	0.03	0.09	0.04	0.03	0.04	0.04	0.03	0.02	0.02	0.05	0.02	0.048	0.035	0.052	0.031	0.0587	0.053	0.049
Vanadium	µg/L	<0.2	0.2	0.5	<1	0.6	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	0.33	0.36	0.25	0.2	<0.2	0.26	0.56	0.22	<0.20	<0.20	<0.50	0.27
Zinc	µg/L	<4	<4	6	6	<4	<4	10	3	1	1	1	2	1	1	1	1	1	2	2	1	2.74	1.54	0.38	0.47	3.75	<1.0	2.17
Dissolved Metals																												
Aluminum	µg/L	20	<10	<10	<10	<10	<10	4	11	23	6	7	7	3	3	2	7	10	9	5	7	3	40	3	3	2	2	6
Antimony	µg/L	0.9	0.7	0.6	0.8	0.6	<0.4	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.020	0.021	<0.020	<0.020	<0.020	<0.020	<0.020
Arsenic	µg/L	<0.4	0.6	<0.4	<0.4	<0.4	<0.4	0.19	0.23	0.51	0.22	0.18	0.27	0.44	0.29	0.13	0.25	0.6	0.26	0.2	0.25	0.216	0.289	0.406	0.257	0.178	0.322	0.254
Barium	µg/L	20	20	20	20	20	20	30	20	20	20	20	20	20	20	30	20	30	20	20	20	23	14	21	18.5	26	19.4	26.1
Beryllium	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	13	17	14	11	13	5	<50	<50	<20	<20	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<20	<20	12	16	16
Cadmium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.009	<0.005	<0.005	<0.005	0.011	0.006	0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	0.9	<0.4	1.3	<0.4	<0.4	0.6	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	<0.1	<0.1	<0.1	<0.10	<0.10	0.2	<0.10	<0.10	<0.10	0.11
Cobalt	µg/L	0.4	0.5	0.2	0.8	3.3	<0.1	0.032	0.04	0.078	0.029	0.03	0.044	0.05	0.039	0.031	0.046	0.089	0.036	0.039	0.042	0.027	0.068	0.054	0.037	0.021	0.033	0.029
Copper	µg/L	0.7	<0.6	<0.6	<0.6	<0.6	<0.6	0.23	0.35	0.11	0.09	0.17	3.2	0.05	0.09	2.4	2.7	0.13	0.1	0.12	0.1	0.057	0.25	0.082	0.093	0.117	0.084	0.079
Iron	µg/L	200	1,000	400	400	100	400	200	400	200	400	200	400	100	200	100	400	1,000	500	400	300	398	946	262	340	227	64	259
Lead	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.03	0.05	0.01	0.01	0.06	0.01	0.01	0.02	0.02	0.03	0.02	0.01	0.03	0.01	<0.0050	0.081	0.047	0.008	0.0051	<0.0050	0.016
Lithium	µg/L	3	3	3	3	3	2	4	3	5	4	4	3	4	4	4	3	3	3	4	3	3.49	1.93	3.4	3.45	3.89	3.93	3.89
Manganese	µg/L	10	13	9	14	8	14	15	9	39	1	6	6	12	9	19	7	10	2	19	11	32	20	21	10	15	1	2
Mercury	µg/L	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0014	<0.0006	0.002	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0024	0.002	0.0009	<0.001	0.0011	0.000382	0.00296	0.00069	0.00037	0.0002	0.00058	<0.00011
Molybdenum	µg/L	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.3	0.1	0.3	0.4	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.184	0.165	0.243	0.21	0.236	0.285	0.214
Nickel	µg/L	0.2	<0.1	0.5	0.5	1	0.7	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.2	0.1	0.3	0.5	0.3	0.1	0.2	0.128	0.551	0.174	0.165	0.101	0.2	0.304
Selenium	µg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.043	0.042	<0.04	<0.04	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Silver	µg/L	<0.2	<0.2	<0.0005	-	-	0.012	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	40	50	50	40	60	50	60	30	60	50	50	40	60	50	60	40	60	40	60	40	52	27	56	48	56	48	55
Thallium	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	0.5	1.2	<0.3	<0.3	<0.3	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	0.89	<0.50	<0.50	<0.50	<0.50	<0.50
Uranium	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.05	0.02	0.05	0.03	0.05	0.03	0.04	0.04	0.04	0.02	0.02	0.02	0.04	0.02	0.044	0.018	0.048	0.031	0.054	0.042	0.048
Vanadium	µg/L	0.3	0.4	0.6	<1	<0.1	<0.1	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	0.23	<0.20	0.32	0.21	<0.20	<0.20	<0.20	<0.20
Zinc	µg/L	11	<2	<2	7	<2	<1	3	2	0.4	1	1	3	1	2	2	1	1	1	1	0.4	0.3	0.11	1.44	0.44	0.43	<0.10	1.48

000264

Table IV-1: Compiled Water Quality Data from the Firebag River Wateshed, 2006 to 2018

Parameter	Unit	Firebag River Stations						
		FR-1	FR-1	FR-1	FR-1	FR-1	FR-1	FR-1
		18-Mar-16	28-Aug-17	26-Oct-17	8-Mar-18	14-May-18	5-Sep-18	15-Oct-18
Field Measured								
pH	-	6.6	9.1	7.9	6.6	7.6	8.1	7
Specific conductivity	µS/cm	206	205	153	229	111	198	210
Temperature	°C	-0.1	19.2	0.7	0.0	10.3	6.5	0.3
Dissolved oxygen	mg/L	4.0	14.9	12.7	5.4	11.0	13.7	28.5
Conventional Parameters								
pH	-	7.4	9.0	8.1	7.8	8.0	8.2	8.2
Specific Conductivity	µS/cm	220	200	170	230	120	210	200
Hardness	mg/L	108	110	82	120	65	110	96
Total alkalinity, as $CaCO_3$	mg/L	110	100	84	110	56	100	96
Total dissolved solids	mg/L	140	120	110	140	100	110	130
Total suspended solids	mg/L	<1.0	<1.0	5.5	<1.0	18	<1.0	5.9
Total organic carbon	mg/L	4.5	9	11	6.4	15	9.3	7.4
Dissolved organic carbon	mg/L	4.5	8	12	5.5	15	9	9.9
Colour	TCU	17	31	48	38	92	52	37
Major Ions								
Calcium	mg/L	28.8	30	22	29	18	28	25
Magnesium	mg/L	8.8	8.7	6.8	9.8	5.2	8.1	7.9
Potassium	mg/L	1.11	0.77	0.68	0.99	0.59	0.6	0.54
Sodium	mg/L	3.61	3.4	3.3	3.9	2.7	3.2	3.4
Bicarbonate	mg/L	130	100	100	140	69	130	120
Carbonate	mg/L	<0.50	10	<1.0	<1.0	<1.0	<1.0	<1.0
Chloride	mg/L	1.4	<1.0	1.1	4.1	<1.0	<1.0	<1.0
Sulphate	mg/L	1.9	<1.0	<1.0	1.6	<1.0	<1.0	<1.0
Sulphide	mg/L	0.0055	<0.0019	<0.0019	<0.0019	<0.0019	0.0023	<0.0019
Nutrients and Biological Indicators								
Nitrate + nitrite	mg-N/L	0.22	<0.014	<0.014	0.31	<0.014	<0.014	<0.014
Total ammonia	mg-N/L	0.16	0.032	<0.015	0.052	<0.015	<0.015	<0.015
Total Kjeldahl nitrogen	mg-N/L	0.32	0.4	0.43	0.38	0.48	0.43	0.42
Total phosphorus	mg-P/L	0.059	0.021	0.05	0.078	0.061	0.073	0.053
Dissolved phosphorus	mg-P/L	0.025	0.0083	0.018	0.05	0.033	0.028	0.023
Biochemical oxygen demand	mg/L	<2.0	2.1	2.6	<2.0	2.2	<2.0	<2.0
General Organics								
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	mg/L	-	<0.0020	<0.0020	<0.0020	0.0051	0.0047	<0.0020
Total phenolics[(b)]	mg/L	<0.0020	-	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals								
Aluminum	µg/L	5	3	18	9	60	13	27
Antimony	µg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Arsenic	µg/L	0.236	0.44	0.29	0.29	0.37	0.35	0.29
Barium	µg/L	26.4	20	22	27	21	21	23
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01
Boron	µg/L	12	13	11	14	18	14	12
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	<0.10	<0.10	<0.10	<0.10	0.13	<0.10	0.11
Cobalt	µg/L	0.032	0.054	0.059	0.041	0.1	0.047	0.058
Copper	µg/L	<0.050	<0.050	0.25	0.051	0.17	<0.10	<0.10
Iron	µg/L	549	250	630	760	710	470	660
Lead	µg/L	0.007	<0.0050	<0.020	0.0093	0.061	<0.020	0.027
Lithium	µg/L	4.25	4	3.8	4	2.9	3.8	4
Manganese	µg/L	33	16	51	35	60	19	47
Mercury	µg/L	0.00033	0.00071	0.00071	0.00047	0.002	0.00075	0.00076
Methyl mercury	µg/L	<0.00008	<0.00008	<0.00008	<0.00008	0.00012	<0.00008	<0.00008
Molybdenum	µg/L	0.223	0.19	0.14	0.21	0.18	0.16	0.18
Nickel	µg/L	0.094	0.12	0.21	0.096	0.35	0.16	0.2
Selenium	µg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Silver	µg/L	<0.0050	<0.0050	<0.010	<0.0050	<0.010	<0.010	<0.010
Strontium	µg/L	57	57	43	59	38	56	50
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	<0.50	<0.50	<2.0	<0.50	<2.0	<2.0	<2.0
Uranium	µg/L	0.047	0.04	0.025	0.039	0.034	0.037	0.038
Vanadium	µg/L	<0.20	<0.20	0.21	<0.20	0.33	0.21	0.28
Zinc	µg/L	0.64	0.43	<1.0	0.76	1	<1.0	<1.0
Dissolved Metals								
Aluminum	µg/L	2	2	3	3	9	5	3
Antimony	µg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Arsenic	µg/L	0.177	0.41	0.23	0.17	0.31	0.33	0.24
Barium	µg/L	28	19	19	27	15	20	20
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	13	13	11	13	15	13	12
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	µg/L	0.024	0.047	0.032	0.024	0.044	0.04	0.039
Copper	µg/L	0.051	0.073	<0.050	<0.050	0.082	<0.050	<0.050
Iron	µg/L	260	150	260	360	290	290	270
Lead	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	0.0091	0.0062	0.009
Lithium	µg/L	4.58	4.1	3.6	4.3	2.8	4.1	3.8
Manganese	µg/L	16	3	5	16	4	6	11
Mercury	µg/L	0.00031	0.00029	0.00037	0.0002	0.00118	0.00043	0.00045
Molybdenum	µg/L	0.224	0.21	0.15	0.19	0.16	0.16	0.16
Nickel	µg/L	0.088	0.13	0.15	0.088	0.25	0.15	0.13
Selenium	µg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Silver	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	58	59	44	55	35	54	49
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Uranium	µg/L	0.05	0.044	0.028	0.042	0.018	0.034	0.039
Vanadium	µg/L	<0.20	<0.20	<0.20	<0.20	0.27	<0.20	<0.20
Zinc	µg/L	0.5	0.16	0.11	0.37	0.34	0.43	0.1

Table IV-2: Compiled Water Quality Data from the Muskeg Creek Wateshed, 2006 to 2018

Muskeg Creek Stations

Parameter	Unit	IYC-1 18-Jul-07	IYC-1 13-Sep-07	IYC-1 11-Sep-08	IYC-1 28-Mar-10	IYC-1 28-Apr-10	IYC-1 14-Sep-10	IYC-1 4-May-11	IYC-1 8-Sep-11	IYC-1 11-May-12	IYC-1 5-Sep-12	IYC-1 5-Sep-13
Field Measured												
pH	-	-	7.5	-	7.3	6.8	-	7.9	-	7.4	-	-
Specific conductivity	µS/cm	-	148	-	731	96	-	141	-	207	-	-
Temperature	°C	-	7.1	-	8.9	2.4	-	0.1	-	4.1	-	-
Dissolved oxygen	mg/L	-	-	-	7.3	11.6	-	12.1	-	12.6	-	-
Conventional Parameters												
pH	-	8.3	8.0	8.2	7.8	7.7	7.9	7.9	8.5	8.0	8.0	8.5
Specific Conductivity	µS/cm	406	143	202	950	100	134	140	535	190	191	364
Hardness	mg/L	171	74	94	330	50	70	67	201	89	86	174
Total alkalinity, as $CaCO_3$	mg/L	228	72	104	530	46	64	66	284	94	89	190
Total dissolved solids	mg/L	269	134	172	600	88	141	130	359	160	167	245
Total suspended solids	mg/L	4.0	17	<3.0	340	46	29	63	<3.0	4.0	122	7
Total organic carbon	mg/L	22	32	29	41	23	32	21	17	22	32	25
Dissolved organic carbon	mg/L	21	33	27	42	19	34	21	17	20	30	24.6
Colour	TCU	120	170	140	150	120	167	71	86	60	159	127
Major Ions												
Calcium	mg/L	38	16	23	75	13	18	16	56	23	21	46.2
Magnesium	mg/L	15	6.5	8.3	35	4.4	6.2	5.4	18	7.6	7.6	14.3
Potassium	mg/L	1.8	0.6	<0.5	5.0	1.0	<0.5	1.2	1.5	1.7	1.0	0.95
Sodium	mg/L	37	7	9	146	4	5	8	40	12	6	20.2
Bicarbonate	mg/L	278	88	127	650	57	79	81	329	110	108	219
Carbonate	mg/L	<5.0	<5.0	<5.0	<0.5	<0.5	<5.0	<0.5	8.5	<0.5	<5.0	6.2
Chloride	mg/L	<1	2	1	4	1	<1	2	2	4	3	1.3
Sulphate	mg/L	8	4	3	6	<1	2	4	12	<1	2	7.38
Sulphide	mg/L	0.008	0.013	0.007	0.038	<0.002	0.007	<0.002	<0.002	0.006	0.005	0.0051
Nutrients and Biological Indicators												
Nitrate + nitrite	mg-N/L	0.2	<0.1	<0.1	0.46	0.016	<0.071	0.034	<0.071	0.029	0.071	0.071
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	0.18	0.05	0.05
Total Kjeldahl nitrogen	mg-N/L	0.7	0.8	0.8	1.6	0.9	1.9	1.0	0.5	0.7	1.3	0.6
Total phosphorus	mg-P/L	0.06	0.04	0.04	0.05	0.03	-	0.03	0.03	0.03	0.12	0.0514
Dissolved phosphorus	mg-P/L	0.040	0.018	0.031	0.033	0.015	-	0.022	0.021	0.023	0.017	0.034
Biochemical oxygen demand	mg/L	<2.0	<2.0	<2.0	<3.0	<3.0	<2.0	<2.0	<2.0	<2.0	2.0	2
General Organics												
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	0.16	<1.0	<0.02	<1.0	0.37	0.27
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.007	0.009	0.016	0.005	<0.002	0.009	0.005	0.005	0.004	0.009	0.0047
Total recoverable hydrocarbons	mg/L	<1.0	<1.0	<1.0	<2.0	<2.0	<1.0	<2.0	<1.0	<2.0	<1.0	-
Total Metals												
Aluminum	µg/L	290	1,000	120	490	190	1,000	1,000	50	110	2,000	1,070
Antimony	µg/L	0.05	0.03	0.03	0.09	0.02	<0.05	0.05	<0.05	<0.02	0.05	0.05
Arsenic	µg/L	1.3	0.7	0.8	1.8	0.5	0.8	1	0.8	0.5	1.3	1.15
Barium	µg/L	49	25	25	80	18	26	30	64	24	51	45.8
Beryllium	µg/L	0.02	0.03	0.01	0.08	0.02	<0.1	0.06	<0.1	<0.01	0.11	0.1
Boron	µg/L	170	30	50	300	<50	20	40	230	<50	40	90
Cadmium	µg/L	0.01	0.01	<0.006	0.06	0.01	<0.1	0.05	<0.1	0.02	0.02	0.01
Chromium	µg/L	0.5	1.3	<0.3	5.7	0.2	1.1	1.2	<0.3	0.2	3.2	0.991
Cobalt	µg/L	0.33	0.42	0.16	1.72	0.33	0.36	0.96	<0.1	0.18	1.23	0.348
Copper	µg/L	0.8	0.7	0.5	2.3	0.9	0.7	1.6	0.5	0.5	1.7	1.42
Iron	µg/L	1,000	1,000	1,000	3,000	1,000	1,000	3,000	1,000	1,000	3,000	1,460
Lead	µg/L	0.19	0.39	0.1	1.74	0.36	0.37	0.84	<0.1	0.12	1.35	0.267
Lithium	µg/L	14	3	7	36	3	4	5	24	7	6	8.45
Manganese	µg/L	69	41	21	213	33	32	181	52	27	95	33.9
Mercury	µg/L	0.002	0.002	<0.0012	0.0062	0.004	0.05	0.0071	0.001	<0.0006	0.0081	0.0023
Methyl mercury	µg/L	-	-	-	<0.00003	<0.00003	-	0.00015	-	0.00008	-	-
Molybdenum	µg/L	0.66	0.11	0.19	0.46	0.1	0.13	0.24	0.47	0.26	0.16	0.434
Nickel	µg/L	1.2	1.1	0.7	3.7	0.9	0.9	2	<0.1	0.8	2.3	1.78
Selenium	µg/L	<0.3	<0.3	<0.2	0.18	0.04	<0.3	0.08	<0.3	0.05	0.3	0.3
Silver	µg/L	<0.005	<0.005	<0.005	0.016	<0.005	<0.01	0.014	<0.01	<0.005	0.01	0.0733
Strontium	µg/L	130	50	70	200	30	50	50	190	60	70	121
Thallium	µg/L	0.007	0.013	<0.003	0.009	0.003	<0.1	0.02	<0.1	0.004	0.1	0.1
Titanium	µg/L	9.2	22	4.8	10.9	4.6	20	22	1.6	4.7	31.9	15.3
Uranium	µg/L	0.407	0.065	0.096	1.21	0.062	<0.1	0.149	0.531	0.106	0.161	0.34
Vanadium	µg/L	1.2	2.4	0.6	2.1	0.7	2.1	2.6	0.4	0.5	5.4	1.91
Zinc	µg/L	4.8	3.6	0.9	11	2.9	3.8	6	1.2	0.8	7.5	2.17
Dissolved Metals												
Aluminum	µg/L	20	44	22	398	20	35	19	8	21	51	24.1
Antimony	µg/L	0.05	0.03	0.03	0.09	<0.02	<0.05	0.03	<0.05	0.02	0.05	0.05
Arsenic	µg/L	1	0.5	0.7	1.3	0.3	0.5	0.4	0.6	0.5	0.6	0.932
Barium	µg/L	50	20	20	70	20	20	20	60	20	20	39.6
Beryllium	µg/L	0.01	<0.01	0.01	0.04	<0.01	<0.1	<0.01	<0.1	<0.01	0.1	0.1
Boron	µg/L	170	20	50	320	<50	20	40	220	<50	30	88.7
Cadmium	µg/L	0.01	<0.006	<0.006	0.03	<0.005	<0.1	0.02	<0.1	0.01	0.01	0.01
Chromium	µg/L	<0.3	<0.3	<0.3	3.6	<0.1	0.3	0.1	<0.3	<0.1	0.3	0.504
Cobalt	µg/L	0.22	0.09	0.11	1.5	0.15	<0.1	0.3	<0.1	0.14	0.16	0.24
Copper	µg/L	0.7	0.4	0.5	2	0.6	0.5	3.5	0.5	0.4	0.3	0.784
Iron	µg/L	1,000	301	1,000	1,000	224	280	401	470	416	371	883
Lead	µg/L	0.15	0.03	0.04	0.62	0.07	<0.1	0.09	<0.1	0.05	0.1	0.1
Lithium	µg/L	13	2	7	41	4	3	5	24	7	4	8.2
Manganese	µg/L	34	3.2	4.6	240	19	4.8	91	6	20	17	12.5
Mercury	µg/L	<0.05	<0.05	<0.05	0.003	0.002	<0.05	<0.0006	<0.05	0.002	0.05	0.05
Molybdenum	µg/L	0.65	0.09	0.19	0.58	0.14	0.12	0.22	0.44	0.26	0.15	0.429
Nickel	µg/L	1.1	0.6	0.6	3.8	0.6	0.5	0.8	<0.1	0.7	0.4	1.57
Selenium	µg/L	<0.3	<0.3	<0.3	0.2	<0.04	<0.3	0.1	<0.3	<0.04	0.3	0.3
Silver	µg/L	<0.005	<0.005	<0.005	0.01	<0.005	<0.01	<0.005	<0.01	<0.005	0.01	0.01
Strontium	µg/L	130	50	70	220	30	40	40	160	60	60	119
Thallium	µg/L	0.004	0.002	<0.003	0.008	<0.002	<0.1	<0.002	<0.1	0.002	0.1	0.1
Titanium	µg/L	2.9	2	1.7	8.5	<0.5	2	0.8	1.2	1.4	3.7	3.53
Uranium	µg/L	0.39	0.032	0.089	1.3	0.03	<0.1	0.074	0.49	0.11	0.1	0.34
Vanadium	µg/L	0.5	0.3	0.4	1.6	0.2	0.4	0.3	0.3	<0.2	0.6	0.462
Zinc	µg/L	3.8	1.4	0.8	5.3	3.2	2.3	3.6	1.2	0.9	0.6	0.555

Parameter	IYC-1 7-May-14	IYC-1 13-Aug-14	IYC-1 12-Sep-14	IYC-1 19-Jul-15	IYC-1 16-Mar-16	IYC-1 19-Aug-16	IYC-1 1-Apr-17	IYC-1 28-Aug-17	IYC-1 8-Mar-18	IYC-1 14-May-18	IYC-1 5-Sep-18	IYC-1 15-Oct-18	KEL-1 31-May-06	KEL-1 27-Jul-06	KEL-1 5-Oct-06
Field Measured															
pH	7.9	10.4	-	7.8	8.0	7.6	8.2	8.1	7.4	7.5	7.9	7.0	8.5	-	7.9
Specific conductivity	191	204	-	176	821	294	410	459	743	122	250	231	108	-	140
Temperature	0.0	10.7	-	13.9	-0.1	10.9	-3.3	14.1	0.0	6.5	4.3	0.0	17.0	-	8.3
Dissolved oxygen	14.5	7.2	-	10.0	12.9	10.1	11.5	10.1	9.1	12.0	14.0	32.1	12.8	-	11.3
Conventional Parameters															
pH	7.9	8.2	8.4	7.9	8.4	8.4	8.3	8.2	8.3	7.9	8.1	8.2	8.1	8.0	8.1
Specific Conductivity	120	220	298	170	900	380	440	460	750	130	260	210	144	159	177
Hardness	52.9	115	135	90.8	246	168	160	170	220	66	120	95	59	74	84
Total alkalinity, as $CaCO_3$	53	110	156	87	470	200	220	230	380	56	130	99	68	80	85
Total dissolved solids	120	180	219	140	540	270	270	260	400	120	220	150	100	120	153
Total suspended solids	130	37	<3	8.8	<1.0	<1.0	<1.0	3.2	<1.0	47	<1.0	<1.0	9.0	10	8.0
Total organic carbon	19	26	20.8	23	27	21	16	19	19	23	25	20	18	23	29
Dissolved organic carbon	19	21	21.2	24	26	21	16	18	19	21	24	21	17	23	26
Colour	61	120	-	96	90	87	76	86	66	100	100	79	50	25	30
Major Ions															
Calcium	13.3	30.4	36.2	23.1	58.9	44.5	40	44	59	17	31	25	15	18	21
Magnesium	4.65	9.41	10.8	8.06	24.1	13.7	14	15	23	5.5	10	8.2	5.3	7.2	7.8
Potassium	1.42	0.499	0.66	0.347	2.97	0.85	1.8	1.1	2.3	0.82	0.62	0.36	1.2	1.0	0.8
Sodium	4.59	6.73	14.8	6.53	117	25.7	44	43	100	5.2	13	10	8	10	10
Bicarbonate	64	130	185	110	560	240	270	280	460	68	150	120	83	97	104
Carbonate	<0.50	<0.50	<5	<0.50	6.6	3	<0.50	<0.50	<1.0	<1.0	<1.0	<1.0	<5.0	<5.0	<5.0
Chloride	3.5	2.1	1.28	2.1	3.1	3	2.1	3.3	3.6	3.4	4.4	4.6	1	2	1
Sulphate	<1.0	1.6	2.99	<1.0	19	<10	<1.0	4	10	<1.0	<2.0	<1.0	5	6	5
Sulphide	<0.0020	<0.0019	0.0023	<0.0019	<0.0019	0.0047	<0.0019	<0.0019	0.0027	0.0047	0.0045	0.0031	<0.003	0.01	0.005
Nutrients and Biological Indicators															
Nitrate + nitrite	0.019	<0.010	<0.054	<0.020	0.077	<0.020	0.14	<0.014	0.086	<0.014	<0.014	<0.014	<0.1	<0.1	<0.1
Total ammonia	<0.050	<0.050	<0.05	0.4	0.11	<0.050	<0.050	0.019	0.026	0.015	<0.015	<0.015	<0.05	0.07	<0.05
Total Kjeldahl nitrogen	0.65	1.3	0.6	0.7	0.54	0.72	0.63	0.55	0.61	0.5	0.55	0.57	0.8	1.9	1.3
Total phosphorus	0.1	0.035	0.041	0.027	0.067	0.0081	0.057	0.031	0.041	0.039	0.027	0.023	0.02	0.04	0.03
Dissolved phosphorus	0.011	0.024	0.0366	0.02	0.021	0.0061	0.042	0.015	0.022	0.014	0.021	0.017	0.007	0.008	0.004
Biochemical oxygen demand	<2.0	<2.0	<2	<2.0	<2.0	<2.0	2.6	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.0	2.0
General Organics															
Naphthenic acids	<1.0	<1.0	0.68	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	-	-	-	-	-	-	0.0022	<0.0020	<0.0020	0.0045	0.0069	<0.0020	-	-	-
Total phenolics[(b)]	0.0058	0.0031	0.0045	<0.0020	0.008	<0.0020	-	-	-	-	-	-	0.008	0.022	<0.001
Total recoverable hydrocarbons	<2.0	<2.0	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	<1.0	<1.0
Total Metals															
Aluminum	514	162	92	123	26	26	45	16	10	260	67	34	30	30	30
Antimony	0.036	0.032	0.024	<0.050	0.051	0.039	0.025	0.044	0.039	0.033	0.033	<0.020	0.9	0.5	1.4
Arsenic	0.854	1.04	0.809	0.646	0.817	0.991	0.45	0.86	0.58	0.57	0.7	0.49	<0.4	<0.4	0.6
Barium	31.6	32.2	29.1	24.2	54.7	33.7	29	27	47	22	23	18	9	14	19
Beryllium	0.068	0.021	0.01	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	0.017	0.014	0.01	<1	<1	<1
Boron	<50	35	72	<50	423	121	170	140	410	29	56	42	40	40	60
Cadmium	0.031	0.012	0.004	<0.0050	0.008	<0.0050	0.005	<0.0050	0.008	0.0068	<0.0050	<0.0050	<0.2	<0.2	<0.2
Chromium	0.71	0.3	0.27	<0.50	0.13	0.14	0.11	<0.10	<0.10	0.39	0.15	<0.10	<0.8	<0.8	2
Cobalt	1.06	0.463	0.186	0.231	0.52	0.279	0.29	0.18	0.25	0.3	0.19	0.12	<0.2	<0.2	<0.2
Copper	1.67	0.785	0.42	0.45	0.664	0.7	0.4	0.44	0.35	0.65	0.33	0.23	<1	<1	<1
Iron	2,080	1,250	1,170	664	1,080	1,280	800	900	1,000	730	860	620	80	110	100
Lead	1.25	0.391	0.055	0.111	0.055	0.049	0.044	0.041	0.03	0.27	0.071	0.036	<0.1	<0.1	<0.1
Lithium	4.34	4.95	7.2	2.87	31.1	11.3	14	11	24	4.2	6.9	6.1	<6	<6	7
Manganese	137	51.3	32.1	33.3	270	64.2	100	48	49	28	25	25	12	27	19
Mercury	0.00884	0.00199	0.00132	0.00232	0.0028	0.00149	0.00334	0.00159	0.00187	0.00359	0.00158	0.00110	<0.0006	0.001	<0.0006
Methyl mercury	0.00015	0.00021	-	0.00013	0.00014	0.00019	0.00009	0.00021	0.00009	0.00014	0.00015	0.00009	0.00008	<0.00003	0.00005
Molybdenum	0.139	0.245	0.345	0.203	1.32	0.583	0.57	0.4	1	0.19	0.28	0.21	0.1	0.1	0.2
Nickel	2.17	1.43	0.51	1.09	1.32	1.41	0.71	0.96	0.98	1	1	0.62	<0.2	<0.2	0.6
Selenium	0.049	0.07	0.1	0.05	0.092	0.073	0.045	0.12	0.073	0.046	0.05	0.044	<0.4	<0.4	0.9
Silver	0.005	<0.0050	<0.002	<0.0050	0.005	<0.010	<0.0050	<0.010	<0.0050	<0.010	<0.010	<0.010	0.026	0.002	0.018
Strontium	40.5	86	99.3	60.5	165	119	110	98	190	49	84	64	60	60	80
Thallium	0.009	0.005	0.0031	0.0029	0.002	0.002	0.002	<0.0020	0.0023	0.0051	0.0026	<0.0020	<0.1	<0.1	<0.1
Titanium	15.9	3.51	2.21	<5.0	1.35	<2.0	2.3	<2.0	1.3	10	3.2	<2.0	<5	<5	<5
Uranium	0.191	0.126	0.172	0.0588	1.16	0.297	0.42	0.24	0.61	0.057	0.1	0.053	<0.1	<0.1	<0.1
Vanadium	2.06	0.78	0.51	0.52	0.46	0.52	0.31	0.3	0.23	0.95	0.42	0.22	<0.2	0.5	1.1
Zinc	5.94	3.49	0.6	1.8	1.38	<1.0	2.3	2.1	1.8	2.2	<1.0	<1.0	<4	<4	5
Dissolved Metals															
Aluminum	10.2	15.9	8.83	13.5	8.96	10.7	14	6.7	3.9	14	13	9.2	<10	<10	<10
Antimony	0.028	0.032	0.024	0.023	0.048	0.038	0.025	0.038	0.035	0.031	0.025	0.022	0.8	0.6	0.7
Arsenic	0.326	0.867	0.685	0.475	0.69	0.951	0.45	0.84	0.45	0.35	0.63	0.44	<0.4	0.4	0.4
Barium	16	26.7	24.9	23	49.5	33.3	30	35	44	16	23	17	10	20	20
Beryllium	<0.010	0.01	<0.009	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.5	<0.5	<0.5
Boron	<50	33	68.5	20	427	128	190	200	370	26	57	42	40	40	60
Cadmium	<0.0050	0.006	<0.002	<0.0050	<0.0050	0.005	0.007	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.1	<0.1	<0.1
Chromium	<0.10	<0.10	0.1	<0.10	<0.10	0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	1	0.9	0.7
Cobalt	0.131	0.13	0.148	0.0911	0.504	0.251	0.26	0.22	0.24	0.098	0.14	0.11	0.7	1.1	0.3
Copper	0.42	0.768	0.33	0.305	0.62	0.455	0.37	0.32	0.39	0.29	0.24	0.18	0.8	<0.6	<0.6
Iron	165	668	819	331	394	984	790	920	280	150	600	470	46	16	12
Lead	0.05	0.063	0.028	<0.0050	0.012	0.034	0.035	0.018	0.0078	0.017	0.028	0.017	<0.1	<0.1	<0.1
Lithium	3.65	4.74	6.34	3.79	32.5	11.8	15	16	24	3.8	7.4	5.7	5	5	6
Manganese	25.6	3.22	17.5	2.74	277	29.4	100	38	47	7	18	18	2	3	<1
Mercury	0.00232	0.00179	<0.009	0.00147	0.0045	0.00133	0.0024	0.00099	0.0013	0.00157	0.00111	0.00093	<0.0006	<0.0006	<0.0006
Molybdenum	0.185	0.316	0.326	0.183	1.31	0.578	0.58	0.59	0.98	0.17	0.26	0.19	0.1	0.2	0.1
Nickel	0.716	1.17	0.504	0.905	1.38	1.4	0.69	1.3	1	0.61	0.81	0.56	0.1	<0.1	0.6
Selenium	0.046	0.075	0.05	0.045	0.123	0.082	0.057	0.075	0.083	0.055	0.049	0.058	<0.4	0.4	<0.4
Silver	<0.0050	0.007	<0.001	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.2	<0.0005	0.01
Strontium	35.2	83.3	90.9	63.5	187	132	110	140	180	42	81	62	50	60	70
Thallium	<0.0020	0.002	0.0015	0.0023	<0.0020	<0.0020	0.002	0.0023	<0.0020	<0.0020	<0.0020	<0.0020	<0.05	<0.05	<0.05
Titanium	1.58	1.2	1.22	0.63	0.76	1.24	<0.50	<0.50	<0.50	0.93	0.73	0.86	0.3	0.6	<0.3
Uranium	0.063	0.097	0.17	0.0609	1.15	0.316	0.41	0.36	0.64	0.035	0.099	0.048	<0.1	<0.1	<0.1
Vanadium	0.29	0.47	0.28	<0.20	<0.20	0.47	0.25	0.36	<0.20	0.34	0.29	0.26	0.3	<0.1	0.5
Zinc	0.28	1.09	0.6	0.16	0.8	0.73	2.2	0.3	1.1	0.33	0.29	0.23	3	3	5

(a) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(b) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
- = not a licable or no data available; S/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre.

Table IV-2: Compiled Water Quality Data from the Muskeg Creek Wateshed, 2006 to 2018

Muskeg Creek Stations

Parameter	Unit	KEL-1 20-Jul-07	KEL-1 11-Sep-07	KEL-1 8-Jul-08	KEL-1 9-Sep-08	KEL-1 18-Sep-09	KEL-1 11-Sep-10	KEL-1 10-Sep-11	KEL-1 8-Sep-12	KEL-1 7-Sep-13
Field Measured										
pH	-	-	7.8	8.5	-	-	-	-	-	-
Specific conductivity	µS/cm	-	181	160	-	-	-	-	-	-
Temperature	°C	-	11.7	19.9	-	-	-	-	-	-
Dissolved oxygen	mg/L	-	9.0	9.8	-	-	-	-	-	-
Conventional Parameters										
pH	-	8.2	8.1	8.2	8.3	8.2	8.1	8.3	8.1	8.1
Specific Conductivity	µS/cm	182	174	176	176	174	165	187	207	176
Hardness	mg/L	85	69	79	76	77	69	80	77	79.8
Total alkalinity, as $CaCO_3$	mg/L	93	87	84	89	89	81	94	105	87
Total dissolved solids	mg/L	163	157	151	220	152	142	175	156	156
Total suspended solids	mg/L	6.0	13	7.0	4.0	4.0	<3.0	8.0	5.0	3
Total organic carbon	mg/L	28	25	25	25	9.8	23	26	24	27.9
Dissolved organic carbon	mg/L	25	24	24	24	9.8	22	24	23	28.2
Colour	TCU	40	33	46	41	54	27	22	21	69.3
Major Ions										
Calcium	mg/L	19	17	20	19	21	18	20	20	20.2
Magnesium	mg/L	7.6	5.7	7.4	6.8	6.5	6.7	7.5	7.0	7.12
Potassium	mg/L	0.7	<0.5	0.6	0.6	<0.5	<0.5	0.6	0.6	0.86
Sodium	mg/L	10	9	10	10	11	9	11	11	10.6
Bicarbonate	mg/L	113	106	102	108	108	99	115	129	106
Carbonate	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	5
Chloride	mg/L	1	3	2	<1	<1	<1	<1	<1	0.53
Sulphate	mg/L	6	4	5	4	2	2	2	1	3.09
Sulphide	mg/L	0.007	0.008	<0.002	0.005	0.005	0.002	0.003	<0.002	0.0075
Nutrients and Biological Indicators										
Nitrate + nitrite	mg-N/L	<0.1	<0.1	<0.1	<0.1	<0.071	<0.071	<0.071	0.071	0.071
Total ammonia	mg-N/L	<0.05	0.24	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.05
Total Kjeldahl nitrogen	mg-N/L	1.2	1.6	1.2	1.1	1.4	1.9	1.2	1.3	0.93
Total phosphorus	mg-P/L	0.04	0.04	0.02	0.03	0.02	-	0.02	0.02	0.0315
Dissolved phosphorus	mg-P/L	0.009	0.006	0.006	0.008	0.006	-	0.004	0.007	0.0079
Biochemical oxygen demand	mg/L	<2.0	2.0	<2.0	<2.0	2.2	<2.0	2.2	2.0	2
General Organics										
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	0.09	0.16	0.49	0.19	0.43
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.013	0.009	0.008	0.009	0.005	0.01	0.01	0.01	0.0093
Total recoverable hydrocarbons	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-
Total Metals										
Aluminum	µg/L	30	20	<20	20	10	10	10	10	10
Antimony	µg/L	0.03	0.03	0.4	0.02	0.02	<0.05	<0.05	0.05	0.05
Arsenic	µg/L	0.4	0.4	<0.4	0.4	0.4	0.3	0.3	0.3	0.341
Barium	µg/L	18	16	14	12	14	13	13	17	14.9
Beryllium	µg/L	<0.01	<0.01	<1	<0.01	<0.01	<0.1	<0.1	0.1	0.1
Boron	µg/L	50	50	50	50	50	40	50	50	50
Cadmium	µg/L	0.01	<0.006	-	<0.006	<0.006	<0.1	<0.1	0.01	0.01
Chromium	µg/L	<0.3	<0.3	<0.8	<0.3	0.1	<0.3	<0.3	0.3	0.379
Cobalt	µg/L	0.06	0.04	<0.2	0.03	0.02	<0.1	<0.1	0.1	0.1
Copper	µg/L	0.2	0.2	<1	0.1	0.4	<0.1	0.4	0.1	0.163
Iron	µg/L	110	100	80	80	70	90	60	60	114
Lead	µg/L	0.04	0.09	<0.1	0.03	0.01	<0.1	<0.1	0.1	0.1
Lithium	µg/L	6	5	7	6	6	6	6	8	7.3
Manganese	µg/L	41	25	36	28	34	36	50	39	37.8
Mercury	µg/L	0.002	<0.0012	<0.0006	<0.0012	0.001	0.05	0.001	0.001	0.00088
Methyl mercury	µg/L	-	-	<0.00003	-	-	-	-	-	-
Molybdenum	µg/L	0.14	0.12	0.1	0.05	0.03	<0.1	<0.1	0.1	0.1
Nickel	µg/L	0.1	0.1	0.7	<0.06	0.2	<0.1	<0.1	0.1	0.278
Selenium	µg/L	<0.3	<0.3	<0.4	<0.2	<0.3	<0.3	<0.3	0.3	0.3
Silver	µg/L	<0.005	<0.005	0.014	0.008	0.003	<0.01	0.017	0.01	0.0469
Strontium	µg/L	70	70	60	70	70	70	60	70	64.5
Thallium	µg/L	<0.003	<0.003	<0.1	<0.003	<0.003	<0.1	<0.1	0.1	0.1
Titanium	µg/L	1.3	1.2	<5	1.1	0.6	0.7	0.5	0.6	0.979
Uranium	µg/L	0.016	0.011	<0.1	0.009	0.004	<0.1	<0.1	0.1	0.1
Vanadium	µg/L	0.6	0.5	0.5	0.4	0.2	0.2	0.2	0.2	0.215
Zinc	µg/L	1.3	3.2	<4	0.7	0.2	<0.2	0.9	0.6	0.747
Dissolved Metals										
Aluminum	µg/L	2	<1	<10	1	1	<1	1	1	4.72
Antimony	µg/L	0.03	0.03	0.6	0.02	0.02	<0.05	<0.05	0.05	0.05
Arsenic	µg/L	0.4	0.4	<0.4	0.3	0.3	0.3	0.3	0.3	0.328
Barium	µg/L	20	10	10	10	10	10	10	20	13.7
Beryllium	µg/L	<0.01	<0.01	<0.5	<0.01	<0.01	<0.1	<0.1	0.1	0.1
Boron	µg/L	50	50	40	50	50	40	40	50	49.2
Cadmium	µg/L	<0.006	<0.006	<0.1	<0.006	<0.006	<0.1	<0.1	0.01	0.01
Chromium	µg/L	<0.3	<0.3	<0.4	<0.3	0.1	<0.3	<0.3	0.3	0.375
Cobalt	µg/L	0.03	0.03	1.7	0.02	0.02	<0.1	<0.1	0.1	0.1
Copper	µg/L	0.2	0.2	0.6	0.1	0.4	0.3	0.4	0.1	0.113
Iron	µg/L	11	<4	16	6	12	4	<4	4	52
Lead	µg/L	0.01	0.02	0.1	<0.006	0.01	<0.1	<0.1	0.1	0.1
Lithium	µg/L	5	4	6	6	6	6	6	8	7.28
Manganese	µg/L	0.5	0.6	4	0.2	0.4	0.3	0.2	0.2	0.405
Mercury	µg/L	<0.05	<0.05	<0.0006	<0.05	<0.05	<0.05	<0.05	0.05	0.05
Molybdenum	µg/L	0.12	0.12	<0.1	0.04	0.03	<0.1	<0.1	0.1	0.1
Nickel	µg/L	0.1	0.1	0.8	<0.06	0.2	<0.1	<0.1	0.1	0.244
Selenium	µg/L	<0.3	<0.3	<0.4	<0.2	<0.3	<0.3	<0.3	0.3	0.3
Silver	µg/L	<0.005	<0.005	-	<0.005	<0.005	<0.01	0.01	0.01	0.01
Strontium	µg/L	70	70	60	60	70	60	60	70	63.3
Thallium	µg/L	0.002	<0.003	<0.05	<0.003	<0.003	<0.1	<0.1	0.1	0.1
Titanium	µg/L	0.8	0.6	<0.3	0.7	0.4	0.5	0.2	0.4	0.771
Uranium	µg/L	0.013	0.008	<0.1	0.009	0.003	<0.1	<0.1	0.1	0.1
Vanadium	µg/L	0.4	0.3	0.2	0.3	0.2	0.1	0.2	0.2	0.171
Zinc	µg/L	1.2	3.2	<2	0.5	0.2	0.4	0.8	0.5	0.544

Parameter	KEL-1 19-Mar-14	KEL-1 25-May-14	KEL-1 31-Aug-14	KEL-1 11-Sep-14	KEL-1 14-Mar-15	KEL-1 24-May-15	KEL-1 30-Aug-15	KEL-1 19-Mar-16	KEL-1 4-Sep-16	KEL-1 2-Apr-17	KEL-1 29-May-17	KEL-1 7-Mar-18	KEL-1 28-May-18	KEL-1 2-Sep-18	MUC-1 12-Sep-07	MUC-1 25-Mar-08	MUC-1 12-May-08
Field Measured																	
pH	6.9	7.5	7.7	-	7.4	8.5	8.7	7.2	7.4	4.1	8.0	7.0	8.5	8.0	7.4	-	-
Specific conductivity	337	146	142	-	353	168	184	283	193	631	194	287	214	201	206	-	-
Temperature	1.3	16.5	15.6	-	0.1	20.4	19.2	0.4	13.1	-0.8	15.9	1.2	16.5	9.4	8.4	-	-
Dissolved oxygen	1.9	8.3	8.2	-	2.7	8.0	9.0	3.1	9.5	2.4	10.2	2.9	7.6	12.1	9.4	-	-
Conventional Parameters																	
pH	7.6	8.0	7.8	8.1	7.6	8.1	8.1	7.8	8.1	8.1	8.0	8.0	8.2	8.1	7.9	7.7	7.5
Specific Conductivity	320	160	170	180	290	160	180	280	200	290	200	330	210	220	204	275	123
Hardness	132	71.1	79.2	80.6	131	76.4	89.8	129	88.9	130	93	170	99	94	81	131	39
Total alkalinity, as $CaCO_3$	150	72	81	88.6	130	76	88	140	96	140	92	170	100	100	100	147	54
Total dissolved solids	260	140	180	145	200	110	140	190	150	200	140	250	160	150	166	230	-
Total suspended solids	16	2	<1.0	<3	1.1	1.9	2.1	1.9	4.5	2.5	<1.0	<1.0	1.9	1.2	<3.0	3.0	11
Total organic carbon	41	18	22	23.4	31	17	21	28	22	27	19	30	20	23	30	34	26
Dissolved organic carbon	40	18	22	23.3	30	18	21	29	22	26	19	31	19	22	29	36	26
Colour	99	39	40	-	70	30	24	30	20	27	21	49	24	28	130	77	130
Major Ions																	
Calcium	34.7	16.7	20.4	20.9	35.6	20.2	22.7	34.1	21.8	36	24	43	24	23	19	31	11
Magnesium	10.9	5.79	6.86	6.91	10.3	6.31	8.03	10.8	7.85	10	7.9	14	8.1	8.2	6.5	11	3.6
Potassium	1.67	0.897	0.828	0.77	1.6	1.17	1.19	1.98	1.18	1.8	1.3	2.1	1.3	0.99	1.5	1.8	0.8
Sodium	15.2	8.18	9.09	9.8	12.6	8.6	10.3	13.7	9.71	13	10	17	11	11	17	14	8
Bicarbonate	180	88	99	108	160	92	110	170	120	170	110	200	130	130	122	180	66
Carbonate	<0.50	<0.50	<0.50	<5	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	<1.0	<5.0	<5.0	<5.0
Chloride	2.4	1.5	1.4	2.54	2.7	1.2	2.2	2.3	1.4	2.3	1.3	2.8	1.8	2.1	2	2	2
Sulphate	5.5	<1.0	<1.0	3.21	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	4	4	5
Sulphide	0.035	<0.0020	<0.0019	0.0047	<0.0019	<0.0019	<0.0019	<0.0019	0.0056	0.0041	0.0025	0.012	0.0025	<0.0019	0.025	0.021	0.009
Nutrients and Biological Indicators																	
Nitrate + nitrite	0.035	<0.010	0.02	<0.054	0.069	<0.010	<0.020	<0.020	<0.020	0.033	<0.010	0.027	<0.014	<0.014	<0.1	0.2	<0.1
Total ammonia	0.51	<0.050	0.065	<0.05	0.3	<0.050	<0.050	0.061	<0.050	0.056	<0.015	0.45	0.017	0.022	<0.05	0.45	<0.05
Total Kjeldahl nitrogen	2	0.62	0.77	0.98	1.2	0.64	0.79	1	0.61	1.1	0.84	1.9	0.9	1.1	0.9	1.7	1.7
Total phosphorus	0.074	0.008	0.01	0.0115	0.006	0.011	0.026	0.012	0.014	0.0086	0.012	0.013	0.032	0.045	0.02	0.03	0.03
Dissolved phosphorus	0.008	0.004	0.004	0.0016	0.003	0.003	0.0089	<0.0010	0.0073	0.0037	0.0052	0.0016	0.031	0.0027	0.013	0.012	0.016
Biochemical oxygen demand	2.5	<2.0	<2.0	<2	<2.0	<2.0	<2.0	<2.0	2.2	2.1	<2.0	<2.0	<2.0	2.6	<2.0	<2.0	<2.0
General Organics																	
Naphthenic acids	<1.0	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	-	-	-	-	-	-	-	-	-	<0.0020	<0.0020	0.0033	<0.0020	0.0076	-	-	-
Total phenolics[(b)]	0.0071	0.0071	0.0038	0.0029	<0.0020	0.0053	<0.0020	0.0042	<0.0020	-	-	-	-	-	0.007	0.008	0.009
Total recoverable hydrocarbons	<2.0	<2.0	<2.0	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<1.0	<1.0	<1.0
Total Metals																	
Aluminum	20	4	4	7	44	9	6	4	8	16	8	5	18	33	30	30	140
Antimony	0.049	<0.020	<0.020	0.018	0.042	<0.020	<0.020	<0.020	<0.020	0.045	<0.020	0.034	0.037	0.03	0.03	0.03	0.03
Arsenic	0.481	0.244	0.298	0.31	0.416	0.256	0.307	0.343	0.278	0.38	0.25	0.33	0.28	0.32	0.4	0.5	0.3
Barium	38.4	9.51	17.8	16.1	36.6	13.1	18.2	28.7	21.3	30	13	31	16	21	13	23	11
Beryllium	<0.010	<0.010	<0.010	<0.008	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	<0.010	<0.01	<0.01	0.02
Boron	69	<50	45	48.7	55	33	42	54	44	53	34	45	38	41	50	60	60
Cadmium	0.011	<0.0050	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.006	<0.006	<0.006
Chromium	<0.10	<0.10	<0.10	0.15	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.11	<0.10	<0.3	<0.3	<0.3
Cobalt	0.1	0.029	0.028	0.011	0.0847	0.031	0.031	0.032	0.025	0.056	0.024	0.044	0.035	0.035	0.07	0.1	0.1
Copper	0.533	0.094	0.062	0.37	2.13	0.084	<0.050	0.113	0.098	0.27	0.067	0.22	0.15	<0.10	0.2	0.2	<0.1
Iron	955	181	87	106	1,440	65	87	334	156	770	37	920	57	63	300	1,000	250
Lead	0.104	0.025	0.077	0.014	0.275	0.024	0.024	0.008	0.029	0.072	0.065	0.024	0.039	0.2	0.02	0.03	0.08
Lithium	11.6	5.87	7.02	6.07	8.86	5.53	6.12	9.38	7.05	11	6.4	9.4	7.2	8	8	10	6
Manganese	168	18.7	40.9	17.7	189	33.1	43.8	66.4	66.8	140	18	240	36	18	9	48	9
Mercury	0.00192	0.00078	0.001	0.00074	0.00102	0.00066	0.00098	0.00054	0.00071	0.00088	0.00069	0.00069	0.0008	0.00088	0.002	<0.0012	<0.0012
Methyl mercury	0.00032	<0.00008	<0.00008	-	0.00014	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	-	-	-
Molybdenum	0.062	<0.050	0.056	0.032	0.139	0.058	0.06	0.08	<0.050	0.077	<0.050	0.08	0.061	0.056	0.05	0.1	0.22
Nickel	0.593	0.387	0.141	0.024	0.429	0.231	0.136	0.16	0.135	0.3	0.14	0.2	0.2	0.17	0.2	<0.06	0.4
Selenium	0.079	0.043	0.04	0.09	0.054	<0.040	<0.040	0.049	<0.040	0.043	<0.040	0.041	<0.040	<0.040	<0.3	<0.3	<0.3
Silver	<0.0050	<0.0050	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.010	<0.0050	0.014	<0.005	<0.005	<0.005
Strontium	117	55.6	62.7	64.7	106	52.7	70.8	105	74	100	68	100	74	75	70	110	40
Thallium	<0.0020	<0.0020	<0.0020	<0.0009	0.0028	<0.0020	<0.0020	<0.0020	0.004	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.003	<0.003	<0.003
Titanium	<0.50	<0.50	<0.50	0.67	0.66	<0.50	<0.50	<0.50	<0.50	0.72	0.69	<2.0	<0.50	2.1	1.3	1.9	3
Uranium	0.03	0.025	0.014	0.004	0.107	0.014	0.013	0.013	0.017	0.058	0.013	0.016	0.019	0.011	0.025	0.051	0.025
Vanadium	0.25	0.24	0.21	0.16	<0.20	<0.20	0.43	<0.20	0.24	<0.20	<0.20	<0.20	<0.20	<0.20	0.2	0.3	0.5
Zinc	7.41	0.12	0.31	1.1	5.29	2.43	0.38	1.73	0.67	8.7	0.83	3.1	21	2.2	1.8	1.1	0.2
Dissolved Metals																	
Aluminum	3.26	1.24	1.15	1.04	2.42	2.83	2.33	1.49	0.81	14	2.7	1.2	4.3	2.6	6	5	17
Antimony	0.036	<0.020	<0.020	0.018	0.03	<0.020	<0.020	<0.020	<0.020	0.046	<0.020	0.027	0.038	0.02	0.03	0.03	0.03
Arsenic	0.484	0.253	0.28	0.273	0.38	0.25	0.343	0.357	0.267	0.37	0.24	0.43	0.27	0.28	0.4	0.5	0.3
Barium	27.6	9.02	16.4	14.1	33.1	13.6	18.4	30.4	19	33	15	38	15	19	10	20	10
Beryllium	0.011	<0.010	<0.010	<0.009	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01
Boron	67	<50	43	47	52	36	55	53	44	53	33	56	37	40	50	50	50
Cadmium	0.01	<0.0050	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.006	<0.006	<0.006
Chromium	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	<0.10	<0.10	<0.10	0.12	<0.10	<0.10	<0.10	<0.10	<0.3	<0.3	<0.3
Cobalt	0.076	0.02	0.016	0.011	0.068	0.017	0.023	0.032	0.014	0.066	0.018	0.047	0.018	0.025	0.06	0.08	0.07
Copper	0.248	0.085	0.069	0.36	0.298	0.067	0.069	0.069	0.051	0.26	<0.050	<0.050	0.08	0.06	0.2	0.2	<0.1
Iron	629	101	21	47	1,140	17	9	239	4	760	9	640	13	17	213	1,000	135
Lead	0.029	0.011	0.006	0.013	0.034	<0.0050	<0.0050	<0.0050	<0.0050	0.083	0.021	<0.0050	<0.0050	0.0068	0.02	0.03	0.03
Lithium	11.6	5.78	6.44	5.66	9.47	5.81	7.5	9.79	6.97	10	7	12	7.2	8.3	8	10	5
Manganese	101	0.342	0.163	0.86	156	0.133	0.202	35.4	0.118	150	0.25	190	0.16	0.18	2.2	32	2.5
Mercury	0.00149	0.00071	<0.00011	<0.009	0.00059	0.0005	0.00087	0.00045	0.00026	0.00023	0.00022	0.00023	0.0003	0.00042	<0.05	<0.05	<0.05
Molybdenum	0.053	0.064	0.06	0.018	0.138	0.056	0.062	0.093	<0.050	0.074	<0.050	0.094	0.055	0.061	0.05	0.1	0.12
Nickel	0.406	0.191	0.19	0.023	0.35	0.195	0.213	0.162	0.086	0.35	0.12	0.18	0.14	0.15	0.2	<0.06	0.4
Selenium	0.073	<0.040	<0.040	0.09	0.042	<0.040	<0.040	0.047	<0.040	0.04	<0.040	0.043	<0.040	<0.040	<0.3	<0.3	<0.3
Silver	<0.0050	<0.0050	<0.0050	<0.001	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.005	<0.005	<0.005
Strontium	105	52.3	61	59.8	96.4	57.4	75.1	107	70.9	100	73	130	70	73	70	100	40
Thallium	<0.0020	<0.0020	<0.0020	0.0008	<0.0020	<0.0020	<0.0020	<0.0020	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.003	<0.003	<0.003
Titanium	<0.50	<0.50	<0.50	0.54	<0.50	<0.50	<0.50	<0.50	<0.50	0.73	<0.50	<0.50	<0.50	<0.50	0.8	1.4	0.7
Uranium	0.03	0.026	0.013	0.004	0.09	0.014	0.01	0.013	0.012	0.058	0.013	0.021	0.019	0.0081	0.023	0.048	0.018
Vanadium	<0.20	0.23	0.21	0.11	<0.20	0.24	0.25	<0.20	<0.20	0.27	<0.20	<0.20	<0.20	<0.20	0.2	0.3	0.3
Zinc	4.03	0.49	0.17	1.13	4.09	0.19	0.14	1.06	0.21	11	0.5	2.7	2.6	0.81	1.8	1.1	0.2

Table IV-2: Compiled Water Quality Data from the Muskeg Creek Wateshed, 2006 to 2018

Parameter	Unit	Muskeg Creek Stations					
		MUC-1	MUC-1	MUC-1	MUC-1	MUC-1	MUC-1
		15-Jul-08	10-Sep-08	16-Sep-11	8-Sep-12	13-Sep-13	6-Sep-14
Field Measured							
pH	-	-	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	-
Temperature	°C	-	-	-	-	-	-
Dissolved oxygen	mg/L	-	-	-	-	-	-
Conventional Parameters							
pH	-	8.1	8.1	8.3	8.1	8.1	7.9
Specific Conductivity	µS/cm	265	231	428	274	311	296
Hardness	mg/L	128	107	192	100	161	142
Total alkalinity, as $CaCO_3$	mg/L	136	121	232	139	166	147
Total dissolved solids	mg/L	250	170	303	212	255	237
Total suspended solids	mg/L	<3.0	6.0	<3.0	<3.0	3	<3
Total organic carbon	mg/L	34	31	27	6.5	32.6	29
Dissolved organic carbon	mg/L	37	12	27	6.3	31.9	31
Colour	TCU	130	120	87	111	156	-
Major Ions							
Calcium	mg/L	28	22	51	26	43.4	39.2
Magnesium	mg/L	11	9.7	16	8.9	12.9	10.7
Potassium	mg/L	<0.5	<0.5	1.1	1.1	0.91	0.81
Sodium	mg/L	15	18	18	20	14.8	15.7
Bicarbonate	mg/L	166	148	279	170	202	179
Carbonate	mg/L	<5.0	<5.0	<5.0	<5.0	5	<5
Chloride	mg/L	3	1	2	1	0.59	0.87
Sulphate	mg/L	2	2	2	2	1.18	4.52
Sulphide	mg/L	0.02	0.019	0.004	0.004	0.0154	0.0076
Nutrients and Biological Indicators							
Nitrate + nitrite	mg-N/L	<0.1	<0.1	<0.071	0.071	0.071	<0.054
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	0.05	0.05	<0.05
Total Kjeldahl nitrogen	mg-N/L	1.1	1.1	0.9	1.0	0.97	0.73
Total phosphorus	mg-P/L	0.03	0.02	0.04	0.02	0.0416	0.0172
Dissolved phosphorus	mg-P/L	0.019	0.012	0.019	0.013	0.0335	0.0081
Biochemical oxygen demand	mg/L	<2.0	<2.0	2.0	2.0	2	<2
General Organics							
Naphthenic acids	mg/L	1.0	<1.0	0.54	0.03	0.3	0.9
Phenol[(a)]	mg/L	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.006	0.008	0.006	0.008	0.0063	0.0022
Total recoverable hydrocarbons	mg/L	<1.0	<1.0	<1.0	<1.0	-	-
Total Metals							
Aluminum	µg/L	30	20	20	80	52	48
Antimony	µg/L	0.03	0.02	<0.05	0.05	0.05	0.028
Arsenic	µg/L	0.6	0.5	0.5	0.6	0.855	0.515
Barium	µg/L	23	14	42	18	22.8	24.5
Beryllium	µg/L	<0.01	<0.01	<0.1	0.1	0.1	0.01
Boron	µg/L	60	40	70	60	52.9	61.3
Cadmium	µg/L	<0.006	<0.006	<0.1	0.01	0.01	0.003
Chromium	µg/L	<0.3	<0.3	<0.3	0.3	0.3	0.15
Cobalt	µg/L	0.11	0.08	<0.1	0.13	0.218	0.103
Copper	µg/L	<0.1	0.2	0.2	0.1	0.574	0.27
Iron	µg/L	1,000	290	1,000	400	1,040	410
Lead	µg/L	0.03	0.02	<0.1	0.1	0.1	0.03
Lithium	µg/L	9	9	16	11	11.4	7.94
Manganese	µg/L	26	13	67	37	89	23
Mercury	µg/L	<0.0012	<0.0012	0.001	0.002	0.0013	0.00142
Methyl mercury	µg/L	-	-	-	-	-	-
Molybdenum	µg/L	0.07	0.04	<0.1	0.13	0.1	0.163
Nickel	µg/L	0.4	0.3	<0.1	0.2	0.67	0.321
Selenium	µg/L	<0.3	<0.2	<0.3	0.3	0.3	0.07
Silver	µg/L	<0.005	<0.005	<0.01	0.01	0.01	0.004
Strontium	µg/L	130	90	170	100	140	118
Thallium	µg/L	<0.003	<0.003	<0.1	0.1	0.1	0.0031
Titanium	µg/L	1.4	1.7	1.7	2.2	2.9	1.58
Uranium	µg/L	0.063	0.022	0.185	0.1	0.101	0.188
Vanadium	µg/L	0.3	0.2	0.3	0.4	0.273	0.3
Zinc	µg/L	0.4	0.5	4.8	2.7	2.31	1.2
Dissolved Metals							
Aluminum	µg/L	5	6	3	9	8.28	4.52
Antimony	µg/L	0.03	0.03	<0.05	0.05	0.05	0.028
Arsenic	µg/L	0.6	0.4	0.4	0.6	0.777	0.41
Barium	µg/L	20	10	40	20	21.1	20.2
Beryllium	µg/L	<0.01	<0.01	<0.1	0.1	0.1	<0.009
Boron	µg/L	50	40	60	50	50.6	51.8
Cadmium	µg/L	<0.006	<0.006	<0.1	0.01	0.01	<0.002
Chromium	µg/L	<0.3	<0.3	<0.3	0.3	0.3	0.1
Cobalt	µg/L	0.1	0.05	<0.1	0.1	0.216	0.069
Copper	µg/L	<0.1	0.2	0.2	0.1	0.568	0.27
Iron	µg/L	393	183	303	209	780	196
Lead	µg/L	0.02	<0.006	<0.1	0.1	0.1	0.029
Lithium	µg/L	9	9	14	11	11.3	6.69
Manganese	µg/L	14	1.1	30	17	70.7	6.81
Mercury	µg/L	<0.05	<0.05	<0.05	0.05	0.05	<0.009
Molybdenum	µg/L	0.07	0.04	<0.1	0.12	0.1	0.127
Nickel	µg/L	0.4	0.3	<0.1	0.1	0.663	0.292
Selenium	µg/L	<0.3	<0.2	<0.3	0.3	0.3	<0.04
Silver	µg/L	<0.005	<0.005	<0.01	0.01	0.01	0.004
Strontium	µg/L	120	90	140	100	137	101
Thallium	µg/L	<0.003	<0.003	<0.1	0.1	0.1	0.0022
Titanium	µg/L	1.1	1.3	0.9	1.3	1.74	0.95
Uranium	µg/L	0.058	0.019	0.17	0.1	0.1	0.151
Vanadium	µg/L	0.2	0.1	0.2	0.2	0.189	0.16
Zinc	µg/L	0.4	0.5	3.4	2.2	2.28	1.2

Table IV-3: Compiled Water Quality Data from the Muskeg River Wateshed, 2007 to 2018

Parameter	Unit	Muskeg River Stations										
		MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2
		27-Aug-09	25-Oct-09	27-Apr-10	29-Jul-10	25-Oct-10	29-Mar-11	17-Mar-13	17-Apr-13	22-Jul-13	16-Oct-13	18-Mar-14
Field Measured												
pH	-	7.2	-	-	-	-	7.3	6.7	6.6	6.9	-	6.8
Specific conductivity	µS/cm	246	325	-	-	-	514	737	296	198	225	751
Temperature	°C	13.7	2.2	-	-	-	0.1	2.2	0.7	14.6	4.5	1.6
Dissolved oxygen	mg/L	5.9	3.2	-	-	-	5.5	2.1	5.8	2.2	7.3	1.6
Conventional Parameters												
pH	-	7.5	7.8	7.6	8.1	8.0	7.9	7.2	7.6	7.6	7.7	7.2
Specific Conductivity	µS/cm	251	292	180	380	290	580	580	130	250	240	590
Hardness	mg/L	131	160	97	224	156	339	324	64	137	117	298
Total alkalinity, as $CaCO_3$	mg/L	128	160	89	200	150	330	310	62	120	110	290
Total dissolved solids	mg/L	190	198	120	260	200	370	380	84	190	200	390
Total suspended solids	mg/L	<3.0	<3.0	2.0	3.0	<1.0	6.0	600	9.3	31	2.0	4
Total organic carbon	mg/L	20	15	17	24	20	13	30	12	27	24	34
Dissolved organic carbon	mg/L	21	15	15	22	20	11	28	11	27	23	30
Colour	TCU	80	49	44	66	50	35	220	41	95	74	220
Major Ions												
Calcium	mg/L	32	38	23	54	37	82	73	17	34	39	67.5
Magnesium	mg/L	12	16	8.9	20	14	30	27	5.4	12	13	28.7
Potassium	mg/L	0.7	1.7	1.3	0.5	0.7	2.9	1.1	3.0	0.3	1.1	12.1
Sodium	mg/L	4.0	3.0	4.0	3.0	3.0	4.0	4.0	1.0	3.0	4.0	4.55
Bicarbonate	mg/L	156	195	110	250	180	400	380	76	150	140	350
Carbonate	mg/L	<5.0	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50
Chloride	mg/L	<1	1	1	2	1	8	12	1	2	3	8.8
Sulphate	mg/L	4	2	<1	<1	<1	<1	<10	2	<1.0	<1.0	3.4
Sulphide	mg/L	<0.002	0.005	0.006	0.012	0.006	0.005	0.008	<0.002	0.004	<0.002	0.12
Nutrients and Biological Indicators												
Nitrate + nitrite	mg-N/L	<0.071	<0.071	<0.003	<0.003	<0.02	0.018	<0.003	0.14	<0.003	0.011	0.17
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	<0.05	<0.05	0.5	1.4	<0.05	<0.05	0.1	1.5
Total Kjeldahl nitrogen	mg-N/L	1.1	0.62	0.59	1.0	0.79	1.2	2.6	0.25	1.1	0.82	2.5
Total phosphorus	mg-P/L	0.02	0.02	0.02	0.03	0.01	0.06	0.94	0.13	0.08	0.05	1.3
Dissolved phosphorus	mg-P/L	0.016	0.011	0.012	0.015	0.009	0.06	0.33	0.057	0.027	0.032	0.78
Biochemical oxygen demand	mg/L	6.1	<2.0	<4.0	<2.0	<2.0	<2.0	17	6.3	<2.0	<2.0	17
General Organics												
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[a]	mg/L	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[b]	mg/L	0.005	0.004	<0.002	<0.002	<0.002	<0.002	0.013	0.026	0.004	0.004	0.027
Total recoverable hydrocarbons	mg/L	-	<1.0	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals												
Aluminum	µg/L	60	40	40	90	10	10	20	70	70	10	18.6
Antimony	µg/L	<0.4	<0.4	<0.02	0.03	<0.02	0.03	0.02	0.03	0.03	0.04	0.023
Arsenic	µg/L	<0.4	<0.4	0.18	0.46	0.21	0.26	1.06	0.181	0.561	0.333	1.2
Barium	µg/L	22	20	15	37	19	42	76	16	25	18	66.5
Beryllium	µg/L	<1	<1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010
Boron	µg/L	<20	<20	<50	<20	<20	<50	<50	<50	<50	<50	<50
Cadmium	µg/L	-	-	0.005	0.015	<0.005	0.03	<0.005	0.005	0.011	<0.005	<0.0050
Chromium	µg/L	<0.8	<0.8	<0.1	0.2	<0.1	0.8	0.42	0.16	0.18	0.1	0.14
Cobalt	µg/L	<0.2	<0.2	0.08	0.19	0.06	0.36	1.56	0.18	0.18	0.08	1.49
Copper	µg/L	<1	<1	0.4	0.29	<0.05	0.58	0.18	0.45	0.3	0.64	0.284
Iron	µg/L	300	100	200	1,000	200	2,000	14,000	1,000	1,000	200	15,800
Lead	µg/L	<0.1	<0.1	0.06	0.12	0.03	0.55	0.02	0.11	0.09	0.11	0.023
Lithium	µg/L	<6	<6	3	5	4	7	7	1	4	4	6.35
Manganese	µg/L	20	10	10	30	20	300	1,000	100	70	10	958
Mercury	µg/L	<0.0006	<0.0006	0.0007	0.0014	<0.002	0.0009	<0.0006	<0.001	0.0013	0.0009	0.00277
Methyl mercury	µg/L	<0.00003	0.00004	<0.00003	<0.00003	-	<0.00003	0.001	0.00012	0.00049	0.00014	0.00086
Molybdenum	µg/L	0.12	0.14	0.21	0.08	0.08	0.15	<0.05	0.15	0.14	0.15	0.242
Nickel	µg/L	0.93	8.35	0.64	0.7	0.44	2.8	0.91	0.43	0.91	0.67	0.945
Selenium	µg/L	<0.4	<0.4	<0.04	0.05	<0.04	0.05	0.068	<0.04	0.078	<0.04	0.072
Silver	µg/L	0.212	0.132	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0050
Strontium	µg/L	60	60	40	100	70	120	160	30	80	70	138
Thallium	µg/L	<0.1	<0.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002	<0.0020
Titanium	µg/L	<5	<5	1	2.1	<0.5	<0.5	0.7	2.3	0.8	0.5	0.72
Uranium	µg/L	<0.1	<0.1	0.04	0.13	0.04	0.2	0.03	0.02	0.06	0.04	0.055
Vanadium	µg/L	<0.5	1.7	<0.2	0.3	<0.2	<0.2	0.3	0.3	<0.2	0.2	<0.20
Zinc	µg/L	12.4	<4	8.4	1.5	2.8	2.4	0.9	4.2	5.6	2	6.02
Dissolved Metals												
Aluminum	µg/L	<10	<10	25	24	4	5	6	8	9	6	9.66
Antimony	µg/L	<0.4	<0.4	0.03	0.03	<0.02	<0.02	0.02	0.02	0.03	0.03	0.034
Arsenic	µg/L	<0.4	<0.4	0.2	0.4	0.2	0.2	0.5	0.2	0.5	0.3	0.933
Barium	µg/L	20	20	20	30	20	40	40	10	20	20	47.6
Beryllium	µg/L	<0.5	<0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010
Boron	µg/L	20	10	<50	<20	<20	<50	<50	<50	<50	<50	<50
Cadmium	µg/L	<0.1	<0.1	<0.005	0.005	<0.005	0.013	<0.005	<0.005	<0.005	<0.005	<0.0050
Chromium	µg/L	<0.4	0.67	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.10
Cobalt	µg/L	<0.1	<0.1	0.07	0.17	0.05	0.32	1.5	0.16	0.07	0.06	1.23
Copper	µg/L	<0.6	<0.6	0.6	0.3	0.1	4.5	0.2	0.3	0.1	0.4	0.205
Iron	µg/L	120	110	160	190	140	60	4,000	1,000	320	140	8,300
Lead	µg/L	<0.1	<0.1	0.043	0.051	0.009	0.35	0.018	0.045	0.028	0.046	0.01
Lithium	µg/L	4	4	3	5	4	6	7	1	4	4	6.11
Manganese	µg/L	11	16	7	7	11	280	1,000	81	12	1	801
Mercury	µg/L	<0.0006	<0.0006	<0.0006	0.0006	0.003	0.0016	<0.0006	0.002	0.0031	0.00065	0.00322
Molybdenum	µg/L	0.11	0.12	0.2	0.11	0.07	0.08	0.2	0.14	0.14	0.2	0.356
Nickel	µg/L	0.98	0.88	0.52	0.58	0.44	0.45	0.8	0.35	0.68	0.68	0.952
Selenium	µg/L	<0.4	<0.4	<0.04	0.06	<0.04	<0.04	0.06	<0.04	0.08	0.06	0.083
Silver	µg/L	0.0035	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0050
Strontium	µg/L	60	60	40	100	70	120	150	30	80	70	127
Thallium	µg/L	<0.05	<0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0020
Titanium	µg/L	0.8	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.85
Uranium	µg/L	<0.1	<0.1	0.04	0.1	0.04	0.19	0.02	0.01	0.03	0.05	0.061
Vanadium	µg/L	0.13	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.20
Zinc	µg/L	13	1.4	5.7	1.2	1.0	2.1	0.9	2.3	0.4	0.9	2.19

Parameter	Unit	Muskeg River Stations													
		MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2	MR-2
		7-May-14	14-Aug-14	20-Oct-14	16-Mar-15	24-May-15	22-Jul-15	16-Nov-15	19-Mar-16	20-Aug-16	26-Oct-16	4-Apr-17	30-Aug-17	24-Oct-17	10-Mar-18
Field Measured															
pH	-	7.6	9.6	4.7	6.7	6.8	6.9	4.8	6.8	6.1	6.5	7.1	7.0	7.1	7.0
Specific conductivity	µS/cm	192	369	420	432	199	298	655	504	478	268	235	442	291	461
Temperature	°C	1.1	10.9	1.5	0.8	14.9	16.3	-0.2	0.0	11.7	2.0	-3.1	13.0	3.5	0.0
Dissolved oxygen	mg/L	8.1	1.8	5.9	7.6	5.7	4.2	3.7	4.6	1.2	9.6	6.7	0.5	4.5	2.5
Conventional Parameters															
pH	-	7.8	7.7	7.5	7.5	7.9	7.7	7.7	7.5	7.5	8.0	7.7	7.8	8.1	7.8
Specific Conductivity	µS/cm	150	370	310	180	250	310	350	500	420	270	250	430	340	560
Hardness	mg/L	78.8	206	174	79.3	136	160	216	269	225	135	110	240	190	300
Total alkalinity, as $CaCO_3$	mg/L	70	200	170	67	120	160	180	270	250	130	120	230	180	300
Total dissolved solids	mg/L	130	260	260	120	160	220	220	270	310	190	150	280	220	300
Total suspended solids	mg/L	1.3	4.7	4.7	4.5	<1.0	<1.0	3.5	1.3	28	17	<1.0	34	12	130
Total organic carbon	mg/L	17	26	25	19	16	25	17	10	30	19	13	28	20	15
Dissolved organic carbon	mg/L	16	24	23	19	16	25	17	9.9	29	19	12	29	20	12
Colour	TCU	55	140	73	130	46	78	38	17	120	44	56	96	52	23
Major Ions															
Calcium	mg/L	19.4	52.8	44.1	18.5	34.4	39.7	56.6	64.8	57.9	33.4	30	59	47	74
Magnesium	mg/L	7.11	17.9	15.6	8.07	12.3	14.7	18.2	26	19.5	12.5	11	22	19	30
Potassium	mg/L	1.63	0.605	1.4	19.6	1.43	0.702	1.2	1.56	1.64	0.834	2	1.2	2.1	1.4
Sodium	mg/L	2.2	3.37	3.95	1.91	3.41	3.54	4.07	3.07	4.18	3.71	2.6	4.3	4.4	3.5
Bicarbonate	mg/L	86	240	200	82	140	190	220	320	300	150	140	280	220	370
Carbonate	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0
Chloride	mg/L	1.5	1.7	1.8	4.7	1.6	2	2.6	<1.0	3	3.2	2.5	1.9	2.4	1.4
Sulphate	mg/L	<1.0	0.6	<1.0	<100	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.7	<1.0	<1.0	<1.0
Sulphide	mg/L	<0.0020	0.0047	0.0059	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.034	0.0028	<0.0019	0.021	0.0089	0.014
Nutrients and Biological Indicators															
Nitrate + nitrite	mg-N/L	0.014	<0.010	0.04	0.15	<0.010	<0.020	0.068	<0.020	<0.020	<0.020	<0.010	0.022	<0.014	<0.014
Total ammonia	mg-N/L	<0.050	<0.050	<0.050	0.12	<0.050	0.05	0.16	0.7	0.18	0.057	<0.050	0.15	0.053	0.65
Total Kjeldahl nitrogen	mg-N/L	0.5	1.6	0.64	1.3	0.48	0.66	0.73	0.76	1.5	0.94	0.46	1.4	1	2.6
Total phosphorus	mg-P/L	0.025	0.11	0.062	0.36	0.011	0.026	0.031	0.022	0.068	0.059	0.049	0.28	0.11	0.38
Dissolved phosphorus	mg-P/L	0.015	0.041	0.039	0.27	0.0065	0.018	0.019	0.0053	0.02	0.0065	0.014	0.052	0.022	<0.0010
Biochemical oxygen demand	mg/L	<2.0	3.2	<2.0	15	<2.0	<2.0	<2.0	<2.0	6.4	2.1	2.4	4.9	<2.0	3.9
General Organics															
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[a]	mg/L	-	-	-	-	-	-	-	-	-	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Total phenolics[b]	mg/L	0.0048	0.0035	<0.0020	0.042	0.0037	<0.0020	<0.0020	0.0021	<0.0020	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals															
Aluminum	µg/L	119	10.7	18.2	73.2	21.8	7.3	20.9	5	64.4	76.2	62	35	100	110
Antimony	µg/L	0.027	0.036	0.028	0.039	0.031	0.033	<0.050	<0.020	0.037	0.028	0.027	0.036	0.049	0.08
Arsenic	µg/L	0.322	1.43	0.424	0.549	0.298	0.568	0.343	0.267	1.38	0.47	0.45	1.1	0.34	0.42
Barium	µg/L	14.4	49.3	28.2	17	22	28	29.8	37.7	52.9	24	25	56	30	43
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	<20	<20	17	13	10	<50	<10	11	<10	<10	12	<10	<10
Cadmium	µg/L	<0.0050	0.007	<0.0050	0.0081	0.023	<0.0050	<0.0050	<0.0050	<0.0050	0.006	<0.0050	<0.0050	0.0076	0.0072
Chromium	µg/L	0.14	<0.10	0.1	0.3	<0.10	<0.10	<0.50	<0.10	0.2	0.14	<0.10	0.11	0.18	0.18
Cobalt	µg/L	0.08	0.857	0.218	0.34	0.062	0.136	0.275	0.481	0.694	0.269	0.18	0.6	0.21	0.69
Copper	µg/L	0.368	0.374	0.181	0.72	0.356	0.086	0.63	0.077	0.64	0.57	0.2	0.17	0.34	0.25
Iron	µg/L	434	3,550	1,150	1,930	170	462	1,040	1,350	4,930	1,910	1,300	4,600	1,400	3,300
Lead	µg/L	0.079	0.042	0.026	0.232	0.025	<0.0050	0.095	0.006	0.065	0.081	0.053	0.036	0.098	0.072
Lithium	µg/L	2.53	4.48	4.38	2.28	3.81	4.19	7.12	4.68	4.48	3.94	3.4	5.5	4.9	5.3
Manganese	µg/L	10	767	162	147	19	61	269	620	832	185	160	690	140	910
Mercury	µg/L	0.00258	0.00139	0.00102	0.00603	0.00088	0.00131	0.0007	0.00038	0.00167	0.00101	0.00136	0.00192	0.00075	0.00076
Methyl mercury	µg/L	<0.00008	0.0003	0.00016	0.00044	<0.00008	0.00024	<0.00008	<0.00008	0.00027	0.00024	<0.00008	0.00033	0.00013	0.00015
Molybdenum	µg/L	0.268	0.138	0.07	0.367	0.197	0.207	0.099	<0.050	0.138	0.146	0.19	0.083	0.1	<0.050
Nickel	µg/L	0.572	0.961	0.607	0.666	0.65	0.866	0.59	0.33	0.94	0.67	0.45	0.84	0.62	0.51
Selenium	µg/L	0.041	0.078	0.062	<0.040	<0.040	0.072	<0.040	<0.040	0.077	<0.040	<0.040	0.098	<0.040	<0.040
Silver	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.02	<0.0050	<0.010	<0.010	<0.0050	<0.010	<0.010	<0.010
Strontium	µg/L	41.3	117	89.2	35.7	60.3	89	101	97.1	114	66.3	67	120	86	110
Thallium	µg/L	<0.0020	0.002	0.002	0.0036	<0.0020	<0.0020	0.002	<0.0020	0.002	0.002	<0.0020	<0.0020	<0.0020	0.0023
Titanium	µg/L	3.73	<0.50	<0.50	2.56	<0.50	<0.50	<5.0	<0.50	<2.0	2.6	1.3	<2.0	2.1	2.1
Uranium	µg/L	0.04	0.033	0.036	0.0281	0.077	0.0601	0.06	0.057	0.048	0.061	0.12	0.025	0.087	0.062
Vanadium	µg/L	0.43	<0.20	<0.20	0.43	0.31	0.21	<0.50	<0.20	0.39	0.29	0.32	0.28	0.34	<0.20
Zinc	µg/L	0.71	2.95	2.79	8.91	4.03	1.03	2.3	1.18	1.6	2.3	1.4	1.6	2.6	4.1
Dissolved Metals															
Aluminum	µg/L	7.17	6.09	5.98	15	4.18	4.32	3.64	1.15	7.54	3.22	4.4	5.9	4.1	1.3
Antimony	µg/L	0.025	0.041	0.021	0.034	0.032	0.03	0.024	<0.020	0.033	0.025	<0.020	0.027	0.043	0.027
Arsenic	µg/L	0.268	1.01	0.378	0.511	0.321	0.475	0.315	0.221	0.926	0.266	0.33	0.6	0.27	0.24
Barium	µg/L	13.9	41.7	26	14.6	24.6	28.1	24.3	34	42.3	17.5	20	41	29	34
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	<20	<20	19	14	<10	<10	<10	13	<10	<10	12	<10	<10
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0084	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	<0.10	<0.10	<0.10	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	µg/L	0.033	0.368	0.168	0.319	0.053	0.0526	0.205	0.462	0.47	0.027	0.053	0.19	0.13	0.48
Copper	µg/L	1.51	0.135	0.07	0.493	0.177	<0.050	<0.050	<0.050	<0.050	0.079	0.11	<0.050	<0.050	<0.050
Iron	µg/L	179	1,540	463	1,360	96	222	546	69	1,550	50	550	1,000	400	60
Lead	µg/L	0.036	0.012	0.007	0.124	<0.0050	<0.0050	0.066	<0.0050	0.013	<0.0050	0.017	<0.0050	<0.0050	<0.0050
Lithium	µg/L	2.48	4.36	4.51	2.27	4.21	4.36	3.83	4.55	4.52	4.16	3.2	4.9	5.3	4.7
Manganese	µg/L	1	381	114	146	1	1	196	633	533	0	32	110	120	830
Mercury	µg/L	0.00162	0.00188	0.00027	0.00324	0.00061	0.00073	0.00041	0.00026	0.00111	0.00036	0.00071	0.00082	0.00027	0.00024
Molybdenum	µg/L	0.264	0.141	0.093	0.385	0.222	0.23	0.064	<0.050	0.105	0.164	0.19	0.074	0.088	<0.050
Nickel	µg/L	0.67	0.941	0.574	0.55	0.712	0.776	0.537	0.299	0.794	0.464	0.35	0.72	0.48	0.36
Selenium	µg/L	<0.040	0.077	<0.040	<0.040	0.055	0.061	0.058	<0.040	0.068	<0.040	<0.040	0.046	<0.040	<0.040
Silver	µg/L	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	40	108	89	35.8	66.9	81.6	91.1	98.6	120	70.5	58	130	91	110
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	<0.50	<0.50	<0.50	0.64	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Uranium	µg/L	0.036	0.029	0.037	0.0251	0.078	0.0625	0.061	0.053	0.035	0.052	0.11	0.021	0.083	0.045
Vanadium	µg/L	0.25	0.21	<0.20	<0.20	<0.20	0.2	<0.20	<0.20	<0.20	0.2	<0.20	<0.20	<0.20	<0.20
Zinc	µg/L	0.92	1.05	1.73	3.55	0.19	0.6	0.72	0.7	0.63	0.23	0.46	0.52	0.47	1.1

(a) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(b) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
- = not a licable or no data available; S/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre.

Table IV-3: Compiled Water Quality Data from the Muskeg River Wateshed, 2007 to 2018

Muskeg River Stations

Parameter	Unit	MR-2 15-May-18	MR-2 22-Aug-18	MR-2 18-Oct-18	MUR-6 12-Sep-07	MUR-6 10-Sep-08	MUR-6 19-Jul-09	MUR-6 18-Sep-09	MUR-6 28-Mar-10	MUR-6 27-Apr-10	MUR-6 28-Jul-10	MUR-6 15-Sep-10
Field Measured												
pH	-	7.2	6.5	6.6	7.5	-	-	-	-	-	7.8	-
Specific conductivity	µS/cm	202	477	348	289	-	-	-	-	-	681	-
Temperature	°C	12.5	14.6	1.0	8.1	-	-	-	-	-	18.9	-
Dissolved oxygen	mg/L	5.4	1.2	4.3	9.2	-	-	-	-	-	7.8	-
Conventional Parameters												
pH	-	7.9	7.6	7.5	8.1	8.2	7.9	8.3	7.5	7.7	8.2	8.0
Specific Conductivity	µS/cm	220	430	330	288	320	230	303	460	170	370	255
Hardness	mg/L	110	250	180	160	174	134	166	279	101	199	139
Total alkalinity, as $CaCO_3$	mg/L	100	220	170	154	166	121	166	260	89	190	131
Total dissolved solids	mg/L	290	310	220	204	210	166	225	250	120	240	204
Total suspended solids	mg/L	<1.0	4.3	<1.0	<3.0	3.0	21	<3.0	4.0	6.0	5.0	<3.0
Total organic carbon	mg/L	19	25	19	21	23	28	32	10	17	24	26
Dissolved organic carbon	mg/L	19	24	19	21	13	28	32	10	15	23	27
Colour	TCU	65	28	38	82	78	103	99	31	44	61	96
Major Ions												
Calcium	mg/L	29	64	42	34	37	35	42	66	24	59	35
Magnesium	mg/L	10	23	16	14	16	12	14	28	8.9	20	13
Potassium	mg/L	1.3	0.77	1	1.5	<0.5	<0.5	0.6	1.8	1.4	0.5	0.7
Sodium	mg/L	3.1	5.1	4.1	3.0	3.0	3.0	5.0	3.0	3.0	3.0	3.0
Bicarbonate	mg/L	130	270	210	188	203	148	202	310	110	240	160
Carbonate	mg/L	<1.0	<1.0	<1.0	<5.0	<5.0	<5.0	<5.0	<0.5	<0.5	<0.5	<5.0
Chloride	mg/L	1.8	1.7	2.6	1	1	<1	<1	3	<1	2	1
Sulphate	mg/L	<1.0	<1.0	<1.0	5	2	1	2	<1	<1	<1	2
Sulphide	mg/L	<0.0019	0.041	0.0062	0.011	0.011	0.009	0.005	0.005	0.006	0.012	0.006
Nutrients and Biological Indicators												
Nitrate + nitrite	mg-N/L	<0.014	<0.014	<0.014	<0.1	<0.1	<0.071	<0.071	0.024	<0.003	<0.003	<0.071
Total ammonia	mg-N/L	<0.015	0.097	0.031	<0.05	<0.05	<0.05	<0.05	0.3	<0.05	0.1	<0.05
Total Kjeldahl nitrogen	mg-N/L	0.65	0.88	0.57	0.6	0.8	1.2	1.9	0.77	0.59	0.91	1.9
Total phosphorus	mg-P/L	0.011	0.12	0.011	0.02	0.02	0.03	0.02	0.03	0.02	0.02	-
Dissolved phosphorus	mg-P/L	0.0069	0.071	0.0061	0.013	0.013	0.015	0.014	0.011	0.012	0.012	-
Biochemical oxygen demand	mg/L	<2.0	4.9	<2.0	<2.0	<2.0	<2.0	<2.0	<3.0	<4.0	<2.0	<2.0
General Organics												
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.05	<1.0	<1.0	<1.0	0.12
Phenol[a]	mg/L	<0.0020	0.009	<0.0020	-	-	-	-	-	-	-	-
Total phenolics[b]	mg/L	-	-	-	0.008	0.007	0.007	0.004	0.004	<0.002	0.003	0.031
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<1.0	<1.0	-	<1.0	<2.0	-	<2.0	<1.0
Total Metals												
Aluminum	µg/L	9.4	12	3.7	20	10	90	10	10	60	40	30
Antimony	µg/L	0.033	0.022	0.034	0.02	0.03	<0.4	0.03	<0.02	0.02	0.03	<0.05
Arsenic	µg/L	0.29	1.1	0.28	0.31	0.336	0.44	0.504	0.2	0.21	0.45	0.37
Barium	µg/L	20	52	23	22	25	25	26	32	18	35	22
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.01	<0.01	<1	0.0065	<0.01	<0.01	<0.01	<0.1
Boron	µg/L	13	11	<10	11	11	<20	16	<50	<50	<50	12
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.006	<0.006	-	<0.006	<0.005	0.008	0.005	<0.1
Chromium	µg/L	<0.10	<0.10	<0.10	<0.3	<0.3	<0.8	<0.3	<0.1	<0.1	0.1	<0.3
Cobalt	µg/L	0.057	0.6	0.099	0.04	0.06	<0.2	0.06	0.22	0.13	0.15	<0.1
Copper	µg/L	0.15	0.22	<0.10	0.15	0.15	<1	2.49	0.07	0.39	0.19	0.17
Iron	µg/L	150	3,600	260	200	300	1,000	300	1,000	400	400	200
Lead	µg/L	<0.020	<0.020	<0.020	0.02	0.01	0.2	0.01	0.04	0.12	0.05	<0.1
Lithium	µg/L	3.7	5.4	4.1	3	4	<6	9	5	3	5	4
Manganese	µg/L	14	860	84	20	20	40	20	210	40	110	20
Mercury	µg/L	0.00094	0.00140	0.00042	<0.0012	<0.0012	0.0013	<0.0012	<0.0006	0.001	<0.0006	<0.05
Methyl mercury	µg/L	0.0001	0.00055	0.00008	-	-	0.00005	-	<0.00003	<0.00003	0.00008	-
Molybdenum	µg/L	0.18	0.097	0.11	0.09	0.07	0.16	0.09	0.19	0.17	0.12	0.1
Nickel	µg/L	0.55	0.75	0.47	<0.06	0.12	1.52	0.12	0.34	0.59	0.63	0.13
Selenium	µg/L	<0.040	0.072	<0.040	<0.3	<0.2	<0.4	0.289	<0.04	<0.04	0.05	<0.3
Silver	µg/L	<0.010	<0.010	<0.010	<0.005	<0.005	0.2	0.004	<0.005	<0.005	<0.005	<0.01
Strontium	µg/L	60	130	86	80	80	60	90	90	40	100	70
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.003	<0.003	0.12	0.0041	<0.002	0.002	<0.002	<0.1
Titanium	µg/L	<2.0	<2.0	<2.0	1.4	1.6	<5	1.3	<0.5	0.7	0.9	1.6
Uranium	µg/L	0.033	0.014	0.048	0.03	0.03	<0.1	0.07	0.13	0.05	0.12	<0.1
Vanadium	µg/L	<0.20	<0.20	<0.20	0.1	0.1	1.3	0.1	<0.2	<0.2	<0.2	0.2
Zinc	µg/L	1.2	11	<1.0	0.8	0.5	12	0.8	0.9	3.2	0.8	0.9
Dissolved Metals												
Aluminum	µg/L	3.6	6.4	2.9	3	3	<10	5	4	30	30	5
Antimony	µg/L	0.032	0.031	0.025	0.03	0.03	<0.4	0.03	<0.02	0.02	0.03	<0.05
Arsenic	µg/L	0.28	0.87	0.25	0.3	0.3	<0.4	0.5	0.2	0.2	0.5	0.3
Barium	µg/L	20	45	23	20	20	20	30	30	20	40	20
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.01	<0.01	<0.5	0.006	<0.01	<0.01	<0.01	<0.1
Boron	µg/L	14	<10	<10	10	10	20	20	<50	<50	<50	10
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.006	<0.006	<0.1	<0.006	<0.005	0.008	<0.005	<0.1
Chromium	µg/L	<0.10	<0.10	<0.10	<0.3	<0.3	<0.4	<0.3	<0.1	<0.1	0.1	<0.3
Cobalt	µg/L	0.045	0.13	0.059	0.03	0.04	<0.1	0.05	0.23	0.08	0.15	<0.1
Copper	µg/L	0.13	<0.050	<0.050	0.2	0.2	<0.6	1.9	<0.05	0.4	0.1	0.2
Iron	µg/L	83	1,700	130	110	170	230	200	290	240	420	100
Lead	µg/L	<0.0050	<0.0050	<0.0050	0.008	<0.006	<0.1	0.003	0.008	0.099	0.041	<0.1
Lithium	µg/L	3.5	5.4	4.4	3	4	3	8	5	4	5	3
Manganese	µg/L	5	68	33	4	3	20	9	220	19	110	5
Mercury	µg/L	0.00052	0.00100	0.00036	<0.05	<0.05	<0.0006	<0.05	<0.0006	<0.0006	<0.0006	<0.05
Molybdenum	µg/L	0.18	0.088	0.11	0.07	0.07	<0.1	0.09	<0.05	0.16	0.08	<0.1
Nickel	µg/L	0.51	0.74	0.43	<0.06	0.11	0.9	<0.06	0.35	0.6	0.59	<0.1
Selenium	µg/L	0.043	0.085	<0.040	<0.3	<0.2	<0.4	0.24	<0.04	<0.04	0.06	<0.3
Silver	µg/L	<0.0050	<0.0050	<0.0050	<0.005	<0.005	0.0041	<0.005	<0.005	<0.005	<0.005	<0.01
Strontium	µg/L	60	130	86	70	80	70	90	90	40	100	60
Thallium	µg/L	<0.0020	<0.0020	0.0023	<0.003	<0.003	<0.05	0.004	<0.002	<0.002	<0.002	<0.1
Titanium	µg/L	<0.50	<0.50	<0.50	0.9	1.4	0.6	1.3	<0.5	<0.5	<0.5	1.2
Uranium	µg/L	0.029	0.014	0.047	0.03	0.03	<0.1	0.07	0.14	0.04	0.12	<0.1
Vanadium	µg/L	<0.20	<0.20	<0.20	0.09	0.06	0.12	0.12	<0.2	<0.2	<0.2	0.11
Zinc	µg/L	0.96	5.1	0.34	0.8	0.4	<1	0.7	0.5	6.7	0.2	0.9

Parameter	Unit	MUR-6 29-Mar-11	MUR-6 4-May-11	MUR-6 22-Aug-11	MUR-6 14-Sep-11	MUR-6 17-Mar-12	MUR-6 8-May-12	MUR-6 17-Jul-12	MUR-6 16-Sep-12	MUR-6 14-Mar-13	MUR-6 16-Apr-13	MUR-6 22-Jul-13	MUR-6 18-Mar-14	MUR-6 7-May-14	MUR-6 1-Sep-14	MUR-6 16-Mar-15
Field Measured																
pH	-	7.5	7.5	8.0	-	7.8	6.8	-	-	7.4	7.0	7.4	7.3	7.3	7.5	7.1
Specific conductivity	µS/cm	501	115	427	-	638	214	229	-	494	233	169	527	344	331	516
Temperature	°C	0.0	3.8	19.0	-	0.0	9.3	19.3	-	0.0	0.1	15.5	0.0	1.5	12.3	-0.1
Dissolved oxygen	mg/L	10.3	7.7	7.4	-	10.3	11.0	6.1	-	12.0	13.5	6.9	10.6	10.8	7.1	6.2
Conventional Parameters																
pH	-	8.0	7.9	8.2	8.2	7.9	8.1	8.1	7.7	7.8	7.9	7.8	7.7	7.7	8.0	7.7
Specific Conductivity	µS/cm	580	190	440	524	680	260	290	225	500	450	260	550	160	440	510
Hardness	mg/L	365	100	250	265	385	136	162	111	274	239	139	305	81.1	230	268
Total alkalinity, as $CaCO_3$	mg/L	330	94	240	292	380	130	150	99	260	220	130	270	74	230	230
Total dissolved solids	mg/L	360	140	280	307	400	150	220	183	300	270	190	320	120	320	260
Total suspended solids	mg/L	22	2.0	<1.0	5.0	6.0	1.0	<1.0	4.0	1.3	<1.0	2.0	<1.0	2.7	2.7	4.1
Total organic carbon	mg/L	12	17	22	18	16	17	31	36	16	12	27	14	17	23	11
Dissolved organic carbon	mg/L	11	16	22	17	15	16	31	36	16	12	25	13	16	23	11
Colour	TCU	32	44	56	34	30	41	100	143	41	36	99	29	48	73	24
Major Ions																
Calcium	mg/L	83	25	62	69	88	35	41	27	65	63	38	72.1	20.5	64.2	65.4
Magnesium	mg/L	32	9.0	20	24	35	12	14	10	25	22	12	26.6	6.98	22.8	25.4
Potassium	mg/L	2.7	1.8	0.8	0.9	1.9	2.7	0.6	0.8	1.2	1.8	0.2	1.59	1.6	0.77	2.92
Sodium	mg/L	4.0	2.0	3.0	4.0	5.0	3.0	4.0	3.0	4.0	3.0	3.0	3.63	2.17	3.72	3.97
Bicarbonate	mg/L	410	110	290	356	460	150	180	121	320	270	160	330	90	280	280
Carbonate	mg/L	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	5.0	<0.5	<0.5	<0.5	<0.50	<0.50	<0.50	<0.50
Chloride	mg/L	8	2	2	1	3	2	2	1	1	2	2	5.5	1.5	2.3	13
Sulphate	mg/L	<1	5	<1	2	<1	5	<1	5	1	2	<10	1.3	18	<1.0	<1.0
Sulphide	mg/L	0.008	<0.002	0.005	<0.002	0.0086	0.005	<0.002	0.002	<0.002	<0.002	<0.002	<0.0020	<0.0020	<0.0019	<0.0019
Nutrients and Biological Indicators																
Nitrate + nitrite	mg-N/L	0.068	0.004	0.009	<0.071	0.087	<0.003	0.003	0.071	0.034	0.079	<0.003	0.039	<0.010	<0.010	0.065
Total ammonia	mg-N/L	0.5	<0.05	0.1	0.1	0.7	<0.05	0.1	0.1	0.2	0.2	<0.05	0.35	<0.050	0.07	0.48
Total Kjeldahl nitrogen	mg-N/L	1.2	0.9	1.0	0.56	1.4	0.76	1.3	0.94	0.71	0.48	0.84	0.68	0.54	0.73	0.99
Total phosphorus	mg-P/L	0.03	0.04	0.02	0.03	0.02	0.02	0.04	0.02	0.05	0.06	0.05	0.013	0.025	0.02	0.039
Dissolved phosphorus	mg-P/L	0.027	0.013	0.002	0.014	<0.001	0.014	0.029	0.017	0.011	0.012	0.022	0.014	0.014	0.012	0.001
Biochemical oxygen demand	mg/L	<2.0	<2.0	<2.0	<2.0	2.1	<2.0	<2.0	2.1	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	2.5
General Organics																
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	0.2	<1.0	<1.0	<1.0	0.42	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[a]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[b]	mg/L	<0.002	0.005	0.003	0.004	0.005	0.003	0.005	0.012	0.005	0.005	0.003	0.0027	0.0031	0.0049	<0.0020
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<1.0	<2.0	<2.0	<2.0	<1.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals																
Aluminum	µg/L	150	30	20	<3	60	10	10	100	10	20	20	4.53	24.1	13.3	31.6
Antimony	µg/L	0.18	0.03	0.07	<0.05	0.06	<0.02	0.04	0.05	0.02	<0.02	0.03	<0.020	0.022	0.03	0.025
Arsenic	µg/L	0.26	0.23	0.45	0.304	0.28	0.266	0.609	0.408	0.278	0.233	0.592	0.228	0.244	0.563	0.341
Barium	µg/L	39	18	32	42	43	23	30	19	33	30	30	30.8	14.4	27.6	37.1
Beryllium	µg/L	0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	0.1	<0.01	<0.01	<0.01	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	9	<50	19	<50	<50	<50	25	<50	<50	<50	<50	<50	<20	10
Cadmium	µg/L	0.343	0.013	0.019	<0.1	0.0157	<0.005	<0.005	0.01	0.009	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	1.2	<0.1	0.2	<0.3	0.19	<0.1	<0.1	0.3	<0.1	0.11	<0.1	<0.10	<0.10	<0.10	0.1
Cobalt	µg/L	0.5	0.09	0.12	<0.1	0.62	0.07	0.15	0.1	0.19	0.23	0.3	0.311	0.074	0.257	0.475
Copper	µg/L	1.02	0.28	0.42	0.28	0.39	0.12	0.12	0.49	0.22	0.15	0.15	0.061	0.273	0.096	0.364
Iron	µg/L	1,000	500	300	100	1,000	400	1,000	400	1,000	1,000	1,000	749	388	625	1,710
Lead	µg/L	3.45	0.06	0.09	<0.1	0.15	0.01	0.01	0.1	0.07	0.02	0.04	<0.0050	0.041	0.024	0.276
Lithium	µg/L	27	3	5	6	7	4	5	4	5	5	4	4.92	2.49	5.28	5.25
Manganese	µg/L	380	30	70	200	1,000	30	80	30	200	280	210	490	31	176	640
Mercury	µg/L	<0.0006	<0.0006	<0.0006	0.0006	0.0009	<0.0006	<0.0006	0.0018	<0.0006	<0.001	0.0014	0.000531	0.00595	0.00113	0.00105
Methyl mercury	µg/L	<0.00003	0.00005	<0.00003	-	0.00008	0.00009	0.00052	-	0.00013	0.00013	0.00035	0.00009	<0.00008	0.0001	0.00017
Molybdenum	µg/L	0.1	0.16	0.08	<0.1	0.12	0.18	0.16	0.13	<0.05	0.07	0.12	<0.050	0.179	0.106	0.138
Nickel	µg/L	1.11	0.66	0.65	<0.1	0.77	0.48	0.7	0.1	0.39	0.39	0.76	0.42	0.486	0.743	0.55
Selenium	µg/L	<0.04	0.05	0.06	<0.3	0.053	<0.04	0.074	0.3	0.047	<0.04	0.076	<0.040	<0.040	0.054	<0.040
Silver	µg/L	<0.005	<0.005	0.036	<0.01	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	130	50	110	110	140	60	90	50	110	90	80	131	39.5	124	144
Thallium	µg/L	0.003	<0.002	<0.002	<0.1	<0.002	<0.002	<0.002	0.1	<0.002	<0.002	0.002	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	8.9	0.9	0.6	1.1	0.8	<0.5	<0.5	2.3	0.5	0.6	0.9	<0.50	1.05	<0.50	0.75
Uranium	µg/L	0.24	0.05	0.1	0.11	0.11	0.06	0.03	0.1	0.1	0.07	0.03	0.119	0.022	0.094	0.136
Vanadium	µg/L	0.3	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.20	<0.20	<0.20	0.27
Zinc	µg/L	4.1	2.6	2.4	0.7	13.6	0.4	0.7	1.6	1.9	1.5	1.2	0.65	0.87	1.93	5.13
Dissolved Metals																
Aluminum	µg/L	47	9	6	1	2	4	7	10	3	4	6	1.91	4.96	4.72	1.56
Antimony	µg/L	0.12	0.02	0.05	<0.05	0.04	<0.02	0.04	0.05	<0.02	<0.02	0.02	0.02	0.02	0.025	0.024
Arsenic	µg/L	0.3	0.2	0.4	0.3	0.2	0.2	0.6	0.4	0.2	0.2	0.5	0.227	0.239	0.545	0.222
Barium	µg/L	40	20	30	40	40	20	30	20	30	30	30	30.5	12.9	27.8	33.4
Beryllium	µg/L	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	0.011	0.1	<0.01	<0.01	<0.01	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	<20	<50	20	<50	<50	<50	20	<50	<50	<50	<50	<50	<20	11
Cadmium	µg/L	0.14	0.006	<0.005	<0.1	0.011	0.006	<0.005	0.01	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	0.9	0.1	0.1	<0.3	<0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.10	<0.10	<0.10	<0.10
Cobalt	µg/L	0.4	0.06	0.11	<0.1	0.59	0.06	0.13	0.1	0.17	0.27	0.17	0.285	0.032	0.263	0.26
Copper	µg/L	0.5	1.4	0.6	0.3	0.3	0.9	0.1	0.4	0.2	0.6	0.1	0.123	0.177	0.129	0.152
Iron	µg/L	1,000	190	100	<4	50	190	1,000	190	210	440	1,000	133	167	363	152
Lead	µg/L	2.5	0.063	0.068	<0.1	0.02	0.023	0.015	0.1	<0.005	0.011	0.006	<0.0050	0.009	0.01	0.01
Lithium	µg/L	12	3	5	6	7	4	5	4	5	5	4	5.21	2.62	4.91	5.78
Manganese	µg/L	370	7	35	190	860	19	58	2	180	300	92	468	1	157	404
Mercury	µg/L	0.0007	<0.0006	<0.0006	<0.05	0.0011	0.0008	0.0016	0.05	<0.0006	<0.001	0.0016	0.000562	0.00124	0.00094	0.00051
Molybdenum	µg/L	0.09	0.19	0.09	<0.1	0.11	0.17	0.19	0.12	0.06	0.07	0.12	0.091	0.234	0.144	0.121
Nickel	µg/L	0.61	0.72	1.5	<0.1	0.64	0.5	0.72	0.1	0.37	0.93	0.61	0.468	0.521	1.26	0.418
Selenium	µg/L	<0.04	<0.04	0.05	<0.3	0.04	<0.04	0.08	0.3	<0.04	<0.04	0.05	0.043	<0.040	0.057	<0.040
Silver	µg/L	<0.005	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	130	50	110	100	140	60	90	50	110	100	80	132	40.5	124	145
Thallium	µg/L	<0.002	<0.002	<0.002	<0.1	<0.002	<0.002	<0.002	0.1	<0.002	<0.002	<0.002	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	µg/L	3.7	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	0.56	<0.50	<0.50	<0.50
Uranium	µg/L	0.23	0.05	0.1	0.1	0.11	0.06	0.03	0.1	0.09	0.07	0.02	0.124	0.02	0.091	0.124
Vanadium	µg/L	<0.2	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	0.17	<0.2	<0.2	<0.2	<0.20	<0.20	<0.20	<0.20
Zinc	µg/L	4	4.8	8.8	0.7	10	1.5	1.4	1.4	0.9	1.2	0.3	0.56	0.71	1.22	0.4

Table IV-3: Compiled Water Quality Data from the Muskeg River Wateshed, 2007 to 2018

Parameter	Unit	Muskeg River Stations																							
		MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	MUR-6	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440
		27-May-15	22-Jul-15	16-Mar-16	21-Aug-16	4-Apr-17	16-May-17	29-Aug-17	10-Mar-18	14-May-18	21-Aug-18	18-Oct-18	17-Apr-08	13-May-08	24-Jun-08	17-Jul-08	14-Aug-08	23-Sep-08	22-Oct-08	19-Nov-08	16-Dec-08	13-Jan-09	19-Feb-09	17-Mar-09	18-Mar-14
Field Measured																									
pH	-	7.6	7.7	6.7	5.0	7.2	-	7.3	7.0	7.2	7.3	6.9	7.2	7.2	7.3	7.0	7.2	7.3	6.8	6.9	7.0	7.4	7.0	6.9	7.1
Specific conductivity	µS/cm	225	329	515	441	226	-	497	505	207	391	356	227	184	310	386	344	343	419	367	491	547	562	567	588
Temperature	°C	15.6	18.7	-0.1	12.5	-2.8	-	13.8	0.1	11.1	14.0	1.6	0.4	9.4	14.9	15.9	15.7	8.9	1.8	0.0	0.2	0.2	0.4	0.5	0.6
Dissolved oxygen	mg/L	5.6	8.0	10.0	5.0	11.3	-	0.8	6.9	9.1	5.0	11.3	7.2	7.2	5.5	4.0	5.3	5.4	3.5	4.1	3.5	2.0	2.4	2.3	3.4
Conventional Parameters																									
pH	-	8.0	8.0	7.8	8.2	7.8	8.1	8.0	7.9	7.9	8.0	7.7	-	7.4	7.5	8.1	7.4	7.7	7.8	7.1	7.1	7.1	7.1	7.1	7.6
Specific Conductivity	µS/cm	260	340	580	440	270	230	510	620	220	460	340	-	186	309	375	345	347	317	359	492	575	589	582	610
Hardness	mg/L	143	186	316	259	130	120	290	320	120	280	180	-	97	164	189	174	168	158	187	224	264	282	288	309
Total alkalinity, as $CaCO_3$	mg/L	120	180	320	230	130	120	270	310	110	260	180	-	95	167	207	189	188	171	194	272	320	327	325	300
Total dissolved solids	mg/L	170	240	310	310	160	150	310	320	160	330	210	-	106	170	198	181	181	166	191	254	302	312	314	360
Total suspended solids	mg/L	13	<1.0	17	1.3	<1.0	<1.0	4	6.7	<1.0	<1.0	<1.0	-	3.0	1.0	1.0	1.0	1.0	<1.0	<1.0	4.0	9.0	8.0	12	5.3
Total organic carbon	mg/L	17	120	15	29	11	15	28	18	21	27	18	-	-	-	-	-	-	-	-	-	-	-	-	20
Dissolved organic carbon	mg/L	17	20	15	13	11	14	28	17	19	31	20	-	19	23	24	27	24	18	18	17	17	17	17	17
Colour	TCU	57	75	26	25	47	39	56	30	75	40	45	-	73	94	72	100	80	66	53	53	54	40	49	53
Major Ions																									
Calcium	mg/L	37.2	46.7	79	70.9	33	29	77	81	32	65	44	-	23	37	46	40	44	37	42	59	69	67	68	82.1
Magnesium	mg/L	12.2	16.9	28.9	19.8	13	11	25	36	11	21	16	-	-	-	-	-	-	-	-	-	-	-	-	20.6
Potassium	mg/L	1.47	0.718	1.69	0.737	2	1.4	1.1	2	1.3	0.77	0.75	-	1.4	0.3	0.3	0.7	1.1	0.7	0.8	1.0	1.4	1.6	1.5	1.5
Sodium	mg/L	3.53	3.56	3.9	3.89	2.5	3.1	4.5	5.1	3.4	4.3	4.2	-	4.0	5.0	5.0	4.0	6.0	5.0	7.0	8.0	10.0	11.0	10.0	10.4
Bicarbonate	mg/L	150	220	390	280	160	140	330	380	130	320	220	-	115	204	253	230	229	208	237	331	390	398	396	370
Carbonate	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	<1.0	<1.0	-	-	-	-	-	-	-	-	-	-	-	-	<0.50
Chloride	mg/L	2.1	1.1	<1.0	2.4	1.6	1.5	1.8	1.5	1.3	1.8	2.5	-	1	1	1	1	1	1	1	2	3	3	4	6.7
Sulphate	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	9	6	<3	<3	<3	<3	<3	<3	<3	<3	<3	<1.0
Sulphide	mg/L	<0.0019	<0.0019	<0.0019	0.01	<0.0019	<0.0019	0.0056	0.0027	<0.0019	0.011	0.0053	-	0.001	0.003	0.004	0.004	0.003	0.003	0.002	0.003	0.003	0.002	0.002	0.0071
Nutrients and Biological Indicators																									
Nitrate + nitrite	mg-N/L	<0.010	<0.020	0.028	<0.020	<0.010	<0.010	<0.014	0.017	<0.014	<0.014	<0.014	-	0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	0.008	0.011	0.036	0.025	<0.010
Total ammonia	mg-N/L	<0.050	0.08	0.74	<0.050	<0.050	<0.015	0.031	0.7	0.018	0.029	0.022	-	-	-	-	-	-	-	-	-	-	-	-	0.82
Total Kjeldahl nitrogen	mg-N/L	0.72	0.76	1.4	0.94	0.49	0.54	0.85	1.4	0.7	1	0.59	-	0.66	0.71	0.94	0.86	0.78	0.67	0.63	0.88	1.3	1.3	1.4	1.2
Total phosphorus	mg-P/L	0.02	0.029	0.068	0.017	0.054	0.014	0.025	0.041	0.01	0.018	0.012	-	0.02	0.04	0.04	0.04	0.03	0.03	0.03	0.06	0.1	0.11	0.13	0.13
Dissolved phosphorus	mg-P/L	0.0094	0.016	0.0021	0.016	0.0036	0.0023	<0.0010	<0.0010	0.011	0.0026	0.0076	-	0.023	0.026	0.024	0.025	0.021	0.019	0.017	0.023	0.02	0.017	0.018	0.008
Biochemical oxygen demand	mg/L	<2.0	<2.0	2.5	<2.0	2.3	<2.0	2.6	2.1	2.1	<2.0	<2.0	-	-	-	-	-	-	-	2.6	1.6	1.9	3.4	1.7	5.8
General Organics																									
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	<0.1	-	-	-	-	-	<0.1	<0.1	-	<0.1	-	<1.0
Phenol[(a)]	mg/L	-	-	-	-	<0.0020	<0.0020	<0.0020	0.0049	0.0044	0.0096	<0.0020	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.0026	<0.0020	0.0032	0.0026	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0054
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	-	-	-	-	-	-	-	-	-	-	-	<2.0
Total Metals																									
Aluminum	µg/L	33.2	8.45	41.9	5	16	11	14	44	6	8.5	4.3	-	40	40	110	20	10	30	40	20	20	10	20	12.8
Antimony	µg/L	<0.050	0.028	<0.050	0.027	<0.020	0.039	0.033	0.026	0.027	0.021	0.022	-	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.01	<0.020
Arsenic	µg/L	0.307	0.604	0.424	0.468	0.35	0.24	0.7	0.43	0.3	0.81	0.28	-	0.2	0.4	0.4	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.271
Barium	µg/L	22	29.8	51	19.2	28	20	46	49	21	38	23	-	17	32	45	36	31	24	28	48	63	64	66	79.8
Beryllium	µg/L	<0.010	<0.010	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	0.006	<0.003	0.01	0.005	0.007	0.004	0.004	<0.003	0.012	0.01	0.012	0.014
Boron	µg/L	<50	10	<50	<10	<10	10	12	<10	17	<10	<10	-	20	27	29	22	21	17	22	29	51	46	48	61
Cadmium	µg/L	<0.0050	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	<0.002	0.005	0.013	0.008	<0.002	<0.002	0.043	0.041	0.023	0.003	0.003	<0.0050
Chromium	µg/L	<0.50	<0.10	<0.50	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.04	0.14	0.37	0.11	0.09	0.1	0.28	0.24	0.46	<0.04	0.45	0.61
Cobalt	µg/L	0.081	0.201	0.954	0.136	0.34	0.088	0.43	1	0.078	0.52	0.1	-	0.04	0.12	0.17	0.1	0.12	0.07	0.11	0.27	0.35	0.33	0.26	0.306
Copper	µg/L	0.4	0.088	0.35	0.41	0.12	<0.10	<0.10	0.11	0.11	<0.10	<0.10	-	<0.05	0.5	0.31	0.18	<0.05	0.14	0.64	0.43	0.24	0.57	0.26	0.125
Iron	µg/L	286	718	2,280	233	1,700	290	750	2,300	240	860	350	-	200	1,000	1,000	500	1,000	400	1,000	2,000	3,000	3,000	4,000	5,940
Lead	µg/L	<0.050	0.0108	0.057	0.026	0.021	<0.020	<0.020	0.048	<0.020	<0.020	<0.020	-	0.03	0.05	0.06	0.02	<0.001	0.01	0.13	0.21	0.05	0.02	0.02	0.014
Lithium	µg/L	3.08	4.21	4.49	3.74	3.3	3.7	5.8	5.7	3.8	5.9	4.4	-	4	6	7	5	6	5	6	8	10	8	10	13.8
Manganese	µg/L	52	131	1,300	50	420	62	840	1,500	30	1,200	100	-	10	70	160	40	110	50	120	1,000	1,000	410	420	491
Mercury	µg/L	0.00114	0.00127	0.00086	0.00089	0.00092	0.00085	0.00112	0.00082	0.00108	0.00120	0.00048	-	0.0016	0.0013	0.0009	0.0008	0.0006	0.0005	0.0006	0.0005	<0.000035	0.0002	0.0005	0.000517
Methyl mercury	µg/L	0.00026	0.0003	0.00015	0.00014	0.0001	0.00009	0.00021	0.00026	0.00012	0.00017	<0.00008	-	-	-	-	-	-	-	-	-	-	-	-	0.00013
Molybdenum	µg/L	0.146	0.123	<0.050	0.061	0.11	0.17	0.11	<0.050	0.14	0.089	0.059	-	0.13	0.08	0.07	0.09	0.06	0.06	0.06	0.04	0.05	0.03	0.04	<0.050
Nickel	µg/L	0.53	0.719	0.43	0.44	0.39	0.37	0.69	0.48	0.47	0.71	0.37	-	0.13	0.73	0.48	0.11	0.09	<0.005	<0.005	<0.005	<0.005	1.42	<0.005	0.202
Selenium	µg/L	0.063	0.05	<0.040	0.049	<0.040	<0.040	0.05	0.044	<0.040	0.07	<0.040	-	<0.1	0.145	0.168	0.14	0.175	0.117	0.093	0.135	0.266	0.27	0.126	<0.040
Silver	µg/L	0.006	<0.0050	<0.0050	<0.010	<0.0050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	0.003	<0.0005	0.003	0.005	0.011	0.081	<0.0005	0.004	0.005	0.02	0.006	<0.0050
Strontium	µg/L	69.5	92.9	102	95.9	72	58	130	140	62	140	78	-	50	100	130	110	120	100	110	160	230	200	220	290
Thallium	µg/L	0.002	<0.0020	0.003	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	-	0.0028	0.0011	0.0029	<0.0003	0.0022	<0.0003	<0.0003	0.0014	0.0064	0.0025	0.0018	<0.0020
Titanium	µg/L	<5.0	0.51	<5.0	<2.0	0.75	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	1.3	1.7	3.6	3.2	1.8	1.6	2.3	2.8	3.6	3.2	3.4	0.96
Uranium	µg/L	0.046	0.0361	0.046	0.027	0.052	0.025	0.075	0.03	0.017	0.03	0.03	-	0.01	0.04	0.06	0.03	0.03	0.03	0.04	0.07	0.1	0.1	0.09	0.044
Vanadium	µg/L	<0.50	<0.20	<0.50	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	-	0.2	0.3	0.6	0.2	0.2	0.2	0.3	0.4	0.7	0.7	0.9	1.5
Zinc	µg/L	3	0.83	6.5	2.9	0.98	<1.0	<1.0	2.1	<1.0	2.5	<1.0	-	0.6	4.6	0.8	0.7	<0.1	0.5	2.3	2	1.3	0.8	0.6	0.97
Dissolved Metals																									
Aluminum	µg/L	5.76	2.99	6.05	1.56	2	2	1.4	1.5	3.2	3.4	1.9	-	3	4	3	2	2	2	3	3	3	3	3	4.37
Antimony	µg/L	0.028	0.028	0.02	0.03	<0.020	0.022	0.032	<0.020	0.026	0.047	0.023	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01	0.01	<0.020
Arsenic	µg/L	0.299	0.534	0.241	0.582	0.2	0.2	0.56	0.32	0.28	0.73	0.26	-	0.2	0.3	0.3	0.4	0.3	0.2	0.1	0.2	0.2	0.2	0.2	0.202
Barium	µg/L	22.6	28.5	38.9	23.9	22	18	41	44	19	35	23	-	20	30	40	30	30	20	30	40	50	50	60	64.6
Beryllium	µg/L	0.039	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	<0.003	<0.003	0.01	<0.003	0.004	0.004	<0.003	<0.003	0.006	0.004	0.012	0.01
Boron	µg/L	15	<10	14	11	<10	<10	12	<10	15	12	<10	-	20	20	30	20	20	20	20	30	40	40	50	61
Cadmium	µg/L	0.011	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	<0.002	0.005	0.005	0.004	<0.002	<0.002	0.019	0.029	0.011	<0.002	0.002	<0.0050
Chromium	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	-	<0.04	0.14	0.32	0.11	0.09	0.06	0.28	0.16	0.32	<0.04	0.43	0.35
Cobalt	µg/L	0.038	0.0896	0.114	0.086	0.046	0.038	0.32	0.96	0.054	0.48	0.093	-	0.04	0.08	0.08	0.08	0.09	0.06	0.09	0.25	0.3	0.28	0.24	0.26
Copper	µg/L	2.15	<0.050	<0.050	0.082	<0.050	<0.050	<0.050	<0.050	0.068	<0.050	<0.050	-	0.6	0.5	0.3	0.2	<0.05	0.1	0.3	0.3	0.2	0.3	0.3	0.346
Iron	µg/L	94	271	23	39	360	69	94	88	130	270	180	-	100	330	450	270	370	250	390	1,000	360	370	370	426
Lead	µg/L	0.011	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	0.008	0.051	0.006	0.02	<0.001	0.004	0.021	0.011	0.005	0.008	0.002	0.014
Lithium	µg/L	4.22	3.7	5.46	4.92	3.1	3.4	5.4	5.7	3.9	5.3	4.8	-	4	5	6	4	6	5	6	7	10	8	10	13.1
Manganese	µg/L	0	1	50	0	1	2	520	1,600	8	960	86	-	4	21	43	15	56	38	110	550	620	390	400	464
Mercury	µg/L	0.00071	0.00081	0.00086	0.00051	0.0005	0.00049	0.00053	0.00034	0.00057	0.00087	0.00037	-	-	-	-	-	-	-	-	-	-	-	-	0.000403
Molybdenum	µg/L	0.129	0.111	<0.050	0.082	0.1	0.11	0.096	<0.050	0.12	0.087	0.077	-	0.11	0.07	0.06	0.09	0.05	0.05	0.06	0.03	0.03	0.02	0.03	<0.050
Nickel	µg/L	0.568	0.599	0.379	0.559	0.28	0.37	0.63	0.46	0.41	0.68	0.38	-	0.1	0.32	0.33	0.11	0.03	<0.005	<0.005	<0.005	<0.005	1.2	<0.005	0.222
Selenium	µg/L	0.05	0.051	<0.040	0.047	<0.040	<0.040	0.058	<0.040	0.043	0.061	<0.040	-	<0.1	<0.1	0.13	0.06	0.09	0.07	0.06	<0.1	0.17	0.26	0.12	<0.040
Silver	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0037	<0.0005	0.0008	0.0009	<0.0005	0.001	<0.0050
Strontium	µg/L	68.1	87.2	128	124	65	55	130	150	58	140	79	-	50	90	120	110	110	90	100	160	210	190	210	277
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	-	0.003	0.001	0.003	<0.0003	0.002	<0.0003	<0.0003	0.001	0.006	0.003	0.002	<0.0020
Titanium	µg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	-	0.6	0.9	1.5	2	1.4	1.4	1.7	2.2	1.9	2.2	2.1	0.66
Uranium	µg/L	0.04	0.0321	0.049	0.036	0.045	0.024	0.075	0.03	0.017	0.031	0.029	-	0.01	0.03	0.05	0.02	0.03	0.03	0.04	0.07	0.09	0.09	0.08	0.035
Vanadium	µg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	-	0.08	0.17	0.23	0.14	0.14	0.14	0.23	0.22	0.31	0.11	0.33	0.45
Zinc	µg/L	0.48	0.24	0.95	2.01	0.11	0.24	0.23	1.1	0.24	1.5	0.31	-	0.6	4.5	0.4	0.7	<0.05	0.5	2	1.2	1.1	0.8	0.6	1.19

Table IV-3: Compiled Water Quality Data from the Muskeg River Wateshed, 2007 to 2018

Parameter	Unit	Muskeg River Stations																					
		AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0440	AB07DA0475	AB07DA0475	AB07DA0475	AB07DA0475
		8-May-14	2-Sep-14	22-Oct-14	17-Mar-15	27-May-15	20-Jul-15	15-Nov-15	15-Mar-16	21-Aug-16	24-Oct-16	5-Apr-17	15-May-17	30-Aug-17	24-Oct-17	9-Mar-18	15-May-18	22-Aug-18	17-Oct-18	13-Feb-07	16-May-07	18-Jul-07	16-Oct-07
Field Measured																							
pH	-	7.2	7.4	7.6	7.0	8.2	7.5	5.9	7.0	6.6	7.1	7.1	7.6	7.2	7.0	6.7	7.3	6.7	6.8	7.7	7.6	7.5	8.2
Specific conductivity	µS/cm	383	356	886	558	250	394	800	8	503	292	238	249	466	446	566	230	486	419	587	222	502	292
Temperature	°C	2.1	11.5	3.9	0.9	13.8	18.0	0.3	1.7	11.9	1.5	-2.8	6.1	13.3	4.2	0.0	11.8	15.6	1.2	0.2	11.1	19.4	5.2
Dissolved oxygen	mg/L	10.7	4.3	9.8	3.2	5.4	6.0	6.2	0.6	3.9	10.3	8.4	8.5	2.3	3.0	4.8	8.3	1.7	6.0	0.4	-	3.7	9.5
Conventional Parameters																							
pH	-	8.1	7.9	7.8	7.5	8.1	7.9	7.7	7.2	7.8	8.0	7.7	8.0	7.9	8.1	7.8	7.9	7.9	7.9	7.9	7.7	7.9	8.1
Specific Conductivity	µS/cm	200	490	470	570	290	420	470	710	510	290	250	260	500	520	620	250	490	400	570	212	455	303
Hardness	mg/L	91.7	255	241	284	149	199	228	345	289	160	120	130	270	280	330	130	290	210	309	111	260	149
Total alkalinity, as $CaCO_3$	mg/L	88	210	200	280	130	210	220	370	260	140	120	130	260	270	310	110	260	200	317	115	269	166
Total dissolved solids	mg/L	130	320	210	320	180	280	290	430	340	190	150	160	340	310	360	170	320	210	316	118	266	162
Total suspended solids	mg/L	<1.0	2.7	10	6.4	1.7	<1.0	14	11	7.1	20	<1.0	<1.0	2.5	10	27	<1.0	1.6	<1.0	10	-	-	<1.0
Total organic carbon	mg/L	14	20	18	20	18	25	20	26	25	20	11	15	23	21	20	20	24	17	-	-	-	-
Dissolved organic carbon	mg/L	13	19	16	18	17	24	19	1.3	22	19	11	16	26	20	19	20	22	18	15	19	19	23
Colour	TCU	39	66	50	46	66	93	61	2.2	84	44	36	46	110	99	48	72	34	46	-	-	-	-
Major Ions																							
Calcium	mg/L	23.5	65.7	62.4	79.8	40.4	47.6	60.4	96.3	82	40	30	33	73	76	100	33	77	54	-	-	-	-
Magnesium	mg/L	8.46	21.2	20.8	20.5	11.6	19.6	18.7	25.5	20.4	13	10	11	20	22	27	11	24	17	-	-	-	-
Potassium	mg/L	1.73	2.04	2.36	1.53	1.96	1.1	1.83	1.78	0.866	1	1.9	1.6	0.9	1.3	1.7	1.6	0.97	1.1	1.5	0.9	1.0	0.7
Sodium	mg/L	3.7	9.75	8.99	9.06	6.85	6.12	7.53	9.23	7.6	5.5	2.3	4.1	6.1	7.8	7.7	4.8	7	6.1	9.0	6.0	8.0	6.0
Bicarbonate	mg/L	110	260	240	340	160	250	270	450	310	170	140	160	320	330	380	140	320	250	386	140	328	202
Carbonate	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-
Chloride	mg/L	4.3	5.7	5.6	6.3	5.6	2.5	5.5	94	4.2	4.8	2	3.3	3.4	5.2	4.6	3.9	3.1	3.8	2	1	2	1
Sulphate	mg/L	6.7	39	41	<1.0	<1.0	<1.0	<1.0	89	12	<1.0	1.6	<1.0	<1.0	<1.0	23	6.9	<1.0	7.1	<3	<3	<3	<3
Sulphide	mg/L	<0.0020	0.0065	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	0.05	0.015	<0.0019	0.0027	<0.0019	0.0084	0.011	0.013	<0.0019	0.011	0.0076	-	-	-	-
Nutrients and Biological Indicators																							
Nitrate + nitrite	mg-N/L	<0.010	<0.010	<0.010	0.017	0.015	<0.020	0.045	2.6	<0.020	<0.020	0.017	<0.010	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.005	0.005	0.011	0.009
Total ammonia	mg-N/L	<0.050	0.092	0.062	0.67	<0.050	0.077	0.13	1.1	0.12	<0.050	0.064	<0.015	0.24	0.45	0.75	0.018	0.15	0.047	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.42	0.86	0.57	1.2	0.7	1	0.79	1.9	1.1	0.54	0.59	0.61	1.1	1.3	1.9	1.2	1.2	0.78	1.4	0.64	0.81	0.75
Total phosphorus	mg-P/L	0.021	0.043	0.035	0.19	0.038	0.047	0.029	0.47	0.017	0.013	0.05	0.018	0.067	0.083	0.19	0.012	0.066	0.027	0.07	0.03	0.05	0.03
Dissolved phosphorus	mg-P/L	0.01	0.014	0.0096	0.003	0.012	0.023	0.011	<0.0010	0.022	0.014	0.027	0.011	0.024	0.018	<0.0010	0.0079	0.021	0.011	0.021	0.009	0.013	0.025
Biochemical oxygen demand	mg/L	<2.0	<2.0	<2.0	5.4	<2.0	<2.0	6.3	14	2	<2.0	2.9	<2.0	2.7	5.8	2.9	<2.0	2.4	<2.0	3.0	-	-	0.9
General Organics																							
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	-	-	-
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	0.0078	<0.0020	-	-	-	-
Total phenolics[(b)]	mg/L	0.0041	0.0039	<0.0020	0.006	0.0025	<0.0020	0.0027	0.0051	0.0023	-	-	-	-	-	-	-	-	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	-	-	-	-
Total Metals																							
Aluminum	µg/L	18.6	17.8	62.1	19.5	12.1	12.8	72.5	12.4	22.1	23	16	7.5	6.1	16	24	5.9	5.5	5.4	20	70	20	10
Antimony	µg/L	<0.020	<0.020	<0.050	<0.020	<0.050	0.023	<0.050	0.03	<0.020	<0.020	<0.020	0.037	<0.020	<0.020	0.026	0.029	<0.020	<0.020	0.02	0.02	0.01	0.03
Arsenic	µg/L	0.186	0.396	0.31	0.325	0.267	0.475	0.286	0.914	0.467	0.19	0.23	0.19	0.51	0.32	0.33	0.26	0.6	0.24	0.2	0.3	0.3	0.1
Barium	µg/L	17.4	40.9	37.8	72.8	28.4	44	39	115	52.6	18	26	20	62	50	63	24	55	28	99	29	90	36
Beryllium	µg/L	<0.010	<0.010	<0.010	0.017	<0.010	<0.010	0.018	0.01	0.014	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01	<0.010	<0.010	<0.003	0.007	0.005	0.006
Boron	µg/L	<50	<20	<50	44	<50	21	<50	31	26	10	14	11	22	23	29	21	21	14	42	27	38	20
Cadmium	µg/L	<0.0050	<0.0050	0.006	<0.0050	<0.0050	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.023	0.003	<0.002	<0.002
Chromium	µg/L	<0.10	<0.10	<0.50	0.61	<0.50	0.1	<0.50	0.54	0.17	<0.10	<0.10	<0.10	0.15	0.24	0.26	<0.10	0.12	0.13	0.38	0.15	0.22	0.14
Cobalt	µg/L	0.066	0.136	0.107	0.217	0.079	0.173	0.157	0.544	0.235	0.064	0.14	0.067	0.33	0.23	0.27	0.068	0.34	0.091	0.23	0.07	0.12	0.05
Copper	µg/L	0.218	0.308	0.29	0.116	0.35	<0.050	0.7	0.072	0.48	0.37	0.089	0.06	<0.10	0.2	<0.10	<0.10	<0.10	<0.10	0.53	0.2	<0.05	0.35
Iron	µg/L	331	790	1,450	7,250	683	1,290	2,600	29,500	2,570	480	1,500	390	4,300	4,900	5,300	260	3,100	720	4,000	1,000	1,000	1,000
Lead	µg/L	0.269	0.059	0.095	0.0203	<0.050	0.0147	0.1	0.012	<0.020	0.025	0.022	0.01	<0.020	0.025	0.026	<0.020	<0.020	<0.020	0.09	0.04	<0.001	0.01
Lithium	µg/L	4.62	11.1	11.3	11.4	6.79	6.75	9.11	12.4	9.88	5.1	3.5	3.7	8.2	8.9	9.8	5.4	7.8	6.8	12	6	9	6
Manganese	µg/L	15	84	65	413	41	90	177	841	506	30	200	21	610	420	520	17	850	100	1,000	20	200	50
Mercury	µg/L	0.00135	0.00103	0.00065	0.00058	0.00082	0.00118	0.00113	0.00061	0.00078	0.0006	0.001	0.00089	0.00077	0.00065	0.00055	0.00105	0.00096	0.00046	-	0.0008	0.002	<0.01
Methyl mercury	µg/L	<0.00008	0.00026	0.0001	0.00019	0.0002	0.00028	0.00012	0.00019	0.00023	0.00012	<0.00008	<0.00008	0.00014	0.00022	0.00014	0.00012	0.00026	0.00009	-	-	-	-
Molybdenum	µg/L	0.176	0.067	0.069	<0.050	0.082	0.072	0.07	<0.050	<0.050	0.091	0.14	0.087	<0.050	<0.050	<0.050	0.13	<0.050	0.06	0.04	0.1	0.06	0.06
Nickel	µg/L	0.541	0.382	0.39	0.278	0.38	0.567	0.45	0.261	0.47	0.35	0.31	0.33	0.39	0.25	0.37	0.42	0.43	0.35	0.09	0.12	<0.005	0.05
Selenium	µg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.046	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.045	<0.040	<0.1	<0.1	<0.1	0.074
Silver	µg/L	<0.0050	0.006	0.012	<0.0050	0.013	<0.0050	<0.0050	0.006	<0.010	<0.010	<0.0050	<0.0050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.0005	0.004	<0.0005	<0.0005
Strontium	µg/L	54.2	174	162	263	98.7	137	134	286	199	65	70	65	180	150	220	73	170	110	220	70	160	100
Thallium	µg/L	<0.0020	<0.0020	0.002	<0.0020	0.002	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0003	0.0012	<0.0003	0.0013
Titanium	µg/L	0.56	0.74	<5.0	1.56	<5.0	<0.50	<5.0	1.1	<2.0	<2.0	0.86	0.56	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.6	1.8	2.1	1.3
Uranium	µg/L	0.022	0.025	0.039	0.039	0.028	0.0429	0.064	0.076	0.057	0.031	0.092	0.033	0.036	0.028	0.12	0.024	0.026	0.039	0.02	0.02	0.05	0.02
Vanadium	µg/L	0.2	0.26	0.56	1.41	<0.50	0.28	0.71	0.95	0.31	<0.20	0.3	<0.20	0.25	0.33	0.42	<0.20	<0.20	<0.20	0.4	0.3	0.3	0.2
Zinc	µg/L	6.32	3.32	1.5	1.7	2.7	4.15	5	3.35	1.5	2.7	0.61	0.89	<1.0	1.3	2.9	1.3	2.8	<1.0	7.4	4.2	0.7	0.6
Dissolved Metals																							
Aluminum	µg/L	2.54	3.87	3.24	3.35	13.7	3.62	8.91	1.61	2.06	2.6	2.9	5.8	3.3	3	2	3	3	2.3	-	-	-	-
Antimony	µg/L	0.02	<0.020	<0.020	<0.020	0.02	0.021	0.033	<0.020	<0.020	<0.020	<0.020	0.047	0.023	0.02	<0.020	0.028	<0.020	<0.020	-	-	-	-
Arsenic	µg/L	0.179	0.364	0.246	0.218	0.275	0.485	0.295	0.244	0.358	0.24	0.19	0.22	0.41	0.24	0.22	0.25	0.51	0.29	-	-	-	-
Barium	µg/L	16.4	40.4	33.3	63.7	28.8	43.8	35.8	57	46	19	22	22	52	49	48	22	44	25	-	-	-	-
Beryllium	µg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	-	-	-
Boron	µg/L	<50	<20	<20	45	26	20	24	41	24	11	13	13	30	24	25	21	18	11	-	-	-	-
Cadmium	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	-	-	-
Chromium	µg/L	<0.10	0.23	<0.10	0.3	<0.10	<0.10	0.14	0.14	<0.10	<0.10	<0.10	<0.10	0.11	0.15	0.14	<0.10	0.12	<0.10	-	-	-	-
Cobalt	µg/L	0.035	0.1	0.066	0.16	0.044	0.116	0.118	0.354	0.081	0.056	0.066	0.065	0.26	0.21	0.22	0.056	0.13	0.068	-	-	-	-
Copper	µg/L	0.124	0.059	<0.050	<0.050	<0.050	<0.050	0.13	<0.050	<0.050	0.11	0.059	0.084	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	-	-	-	-
Iron	µg/L	134	401	410	408	344	571	922	99	318	230	550	390	1,900	780	210	160	790	420	-	-	-	-
Lead	µg/L	0.043	0.056	<0.0050	<0.0050	<0.0050	<0.0050	0.017	<0.0050	<0.0050	0.006	0.0077	0.0073	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	-	-	-
Lithium	µg/L	4.73	11.2	11.6	12.2	7.48	7.02	8.84	13.3	10.1	6.1	3	4.6	7.7	9.6	8.8	5	7.6	6.6	-	-	-	-
Manganese	µg/L	2	61	34	370	0	4	165	754	2	21	68	21	440	440	490	8	83	69	-	-	-	-
Mercury	µg/L	0.00084	0.00078	0.00027	0.00043	0.00055	0.00075	0.00058	0.00041	0.00044	0.00031	0.00052	0.00047	0.00044	0.00031	0.00015	0.00053	0.00070	0.00034	-	-	-	-
Molybdenum	µg/L	0.156	<0.050	0.069	<0.050	0.089	0.067	0.06	<0.050	<0.050	0.086	0.13	0.11	<0.050	<0.050	<0.050	0.12	<0.050	0.06	-	-	-	-
Nickel	µg/L	0.383	0.279	0.266	0.144	0.4	0.52	0.369	0.205	0.32	0.34	0.26	0.35	0.33	0.22	0.28	0.37	0.41	0.29	-	-	-	-
Selenium	µg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.041	<0.040	<0.040	<0.040	0.059	<0.040	-	-	-	-
Silver	µg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	-	-	-	-
Strontium	µg/L	52.8	166	153	259	95	155	134	288	188	74	61	69	160	170	200	72	170	100	-	-	-	-
Thallium	µg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	-	-	-	-
Titanium	µg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.56	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	-	-	-	-
Uranium	µg/L	0.022	0.024	0.034	0.035	0.025	0.0447	0.059	0.071	0.057	0.027	0.085	0.035	0.034	0.03	0.12	0.02	0.022	0.036	-	-	-	-
Vanadium	µg/L	<0.20	<0.20	<0.20	<0.20	<0.20	0.23	0.22	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	-	-	-	-
Zinc	µg/L	0.43	6.49	0.27	0.33	1.64	0.43	2.89	0.61	0.25	2.2	0.36	1.1	0.2	0.68	1.5	0.78	1.1	0.21	-	-	-	-

Table IV-3: Compiled Water Quality Data from the Muskeg River Wateshed, 2007 to 2018

Parameter	Unit	Muskeg River Stations												
		AB07DA0475 12-Feb-08	AB07DA0475 17-Apr-08	AB07DA0475 13-May-08	AB07DA0475 24-Jun-08	AB07DA0475 17-Jul-08	AB07DA0475 14-Aug-08	AB07DA0475 23-Sep-08	AB07DA0475 22-Oct-08	AB07DA0475 19-Nov-08	AB07DA0475 16-Dec-08	AB07DA0475 13-Jan-09	AB07DA0475 19-Feb-09	AB07DA0475 17-Mar-09
Field Measured														
pH	-	7.8	7.1	7.1	7.3	7.2	7.3	7.5	7.2	6.9	6.9	6.9	6.6	7.1
Specific conductivity	µS/cm	521	225	185	320	422	356	371	328	381	488	528	540	544
Temperature	°C	0.3	0.1	10.0	15.5	15.3	15.7	8.4	1.9	0.0	0.1	-0.1	-0.1	0.1
Dissolved oxygen	mg/L	0.2	8.6	6.7	6.0	4.2	6.5	6.6	10.1	5.9	1.1	0.8	0.7	0.7
Conventional Parameters														
pH	-	7.7	6.9	7.4	7.6	8.4	7.5	7.5	7.4	7.2	7.0	7.1	7.0	7.0
Specific Conductivity	µS/cm	554	225	188	318	409	357	377	332	373	491	557	568	561
Hardness	mg/L	290	109	97	166	210	171	182	161	186	224	249	284	272
Total alkalinity, as $CaCO_3$	mg/L	298	117	96	172	230	195	207	176	203	271	339	317	314
Total dissolved solids	mg/L	299	121	102	173	222	185	198	172	198	255	306	305	299
Total suspended solids	mg/L	10	12	4.0	3.0	2.0	4.0	15	1.0	2.0	9.0	8.0	10	10
Total organic carbon	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved organic carbon	mg/L	15	14	20	24	24	26	24	20	19	17	16	15	15
Colour	TCU	-	80	90	128	105	121	97	84	70	53	44	35	29
Major Ions														
Calcium	mg/L	-	29	25	44	54	43	51	41	47	61	68	69	68
Magnesium	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Potassium	mg/L	1.3	2.2	1.4	0.4	0.6	0.8	0.6	0.8	0.8	1.1	<0.1	0.6	<0.1
Sodium	mg/L	8.0	4.0	4.0	5.0	6.0	4.0	6.0	6.0	7.0	8.0	9.0	9.0	8.0
Bicarbonate	mg/L	363	143	117	209	272	238	252	215	247	330	413	386	383
Carbonate	mg/L	-	-	-	-	4.0	-	-	-	-	-	-	-	-
Chloride	mg/L	2	1	1	2	1	1	1	2	2	2	2	2	3
Sulphate	mg/L	6	5	4	4	<3	<3	<3	<3	<3	<3	<3	<3	<3
Sulphide	mg/L	-	0.002	0.001	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.002
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	0.007	0.046	<0.005	0.017	0.055	0.017	0.019	0.013	0.016	<0.005	<0.005	0.005	<0.005
Total ammonia	mg-N/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	1.2	0.91	0.67	0.83	0.97	0.89	0.79	0.78	0.74	1.0	1.3	1.4	1.4
Total phosphorus	mg-P/L	0.06	0.12	0.03	0.06	0.05	0.05	0.05	0.04	0.04	0.08	0.07	0.06	0.07
Dissolved phosphorus	mg-P/L	0.005	0.035	0.018	0.042	0.029	0.035	0.03	0.026	0.027	0.011	0.009	0.01	0.009
Biochemical oxygen demand	mg/L	1.6	2.1	-	-	-	-	-	-	2.5	1.7	2.3	4.5	2.4
General Organics														
Naphthenic acids	mg/L	-	-	<0.1	-	-	-	-	-	<0.1	<0.1	-	<0.1	-
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Metals														
Aluminum	µg/L	20	80	30	20	10	20	30	40	20	10	10	10	10
Antimony	µg/L	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Arsenic	µg/L	0.2	0.3	0.2	0.4	0.3	0.4	0.3	0.2	0.2	0.3	0.2	0.2	0.2
Barium	µg/L	91	38	25	51	71	55	51	39	44	79	90	103	101
Beryllium	µg/L	0.005	0.007	<0.003	0.003	0.006	<0.003	0.007	<0.003	0.005	0.003	0.006	0.006	0.008
Boron	µg/L	39	22	24	34	36	26	25	20	24	32	41	44	43
Cadmium	µg/L	<0.002	0.219	0.002	0.006	<0.002	0.006	<0.002	0.006	0.003	0.042	0.003	0.015	0.007
Chromium	µg/L	0.43	0.17	0.04	0.16	0.96	0.14	0.11	0.08	0.23	0.23	0.28	<0.04	0.3
Cobalt	µg/L	0.29	0.13	0.04	0.1	0.1	0.09	0.08	0.08	0.08	0.22	0.22	0.28	0.22
Copper	µg/L	<0.05	0.29	<0.05	0.33	0.29	0.22	<0.05	0.18	0.13	0.18	0.18	0.38	0.35
Iron	µg/L	4,000	3,000	4,000	2,000	2,000	1,000	2,000	1,000	2,000	4,000	3,000	4,000	4,000
Lead	µg/L	<0.001	0.05	0.03	0.05	0.01	0.01	0.001	0.04	0.01	0.04	0.02	0.02	0.22
Lithium	µg/L	10	3	4	6	8	5	7	6	7	9	10	11	11
Manganese	µg/L	1,000	180	10	90	130	60	80	80	170	1,000	1,000	1,000	480
Mercury	µg/L	-	0.0025	0.0017	0.0015	0.001	0.001	0.0004	0.0005	0.0004	0.0016	<0.000035	0.0003	0.0003
Methyl mercury	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Molybdenum	µg/L	0.06	0.13	0.13	0.07	0.07	0.09	0.05	0.05	0.13	0.03	0.04	0.04	0.04
Nickel	µg/L	0.09	0.16	0.1	0.14	1.38	<0.005	0.11	<0.005	<0.005	<0.005	<0.005	1.6	<0.005
Selenium	µg/L	0.129	<0.1	<0.04	0.142	0.188	0.129	0.091	0.107	0.124	0.161	<0.1	0.258	0.16
Silver	µg/L	0.002	0.046	0.003	<0.0005	0.005	<0.0005	0.005	0.085	<0.0005	0.003	<0.0005	0.041	0.005
Strontium	µg/L	220	70	60	110	140	120	130	110	110	170	180	180	190
Thallium	µg/L	0.0004	0.0024	0.0018	0.0009	0.0012	0.0021	0.001	<0.0003	<0.0003	0.001	<0.0003	0.0015	0.0014
Titanium	µg/L	2.3	3.1	1.3	1.5	1.8	2	2.2	2.2	2	2.7	2.7	2.8	2.7
Uranium	µg/L	0.03	0.03	0.01	0.03	0.05	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03
Vanadium	µg/L	0.4	0.4	0.2	0.3	0.3	0.2	0.3	0.3	0.7	0.3	0.4	0.3	0.4
Zinc	µg/L	1.2	1.3	1.1	2.3	0.9	0.7	0.2	1	0.7	0.7	1	2.7	3.7
Dissolved Metals														
Aluminum	µg/L	-	4	3	4	2	4	2	3	3	2	1	1	1
Antimony	µg/L	-	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Arsenic	µg/L	-	0.2	0.2	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1
Barium	µg/L	-	30	20	50	60	50	50	30	40	60	80	90	90
Beryllium	µg/L	-	<0.003	<0.003	<0.003	0.005	<0.003	0.004	<0.003	0.005	<0.003	<0.003	0.006	0.005
Boron	µg/L	-	20	20	30	30	20	20	20	20	30	40	40	40
Cadmium	µg/L	-	0.08	0.002	0.003	<0.002	0.006	<0.002	<0.002	0.003	0.006	0.003	0.005	0.004
Chromium	µg/L	-	0.15	0.04	0.16	0.32	0.14	0.11	0.04	0.23	0.12	0.22	<0.04	0.28
Cobalt	µg/L	-	0.1	0.04	0.09	0.08	0.07	0.07	0.05	0.07	0.19	0.19	0.25	0.18
Copper	µg/L	-	0.3	0.4	0.3	0.3	0.2	<0.05	0.2	0.1	0.2	0.2	0.4	0.3
Iron	µg/L	-	1,000	190	1,000	1,000	1,000	1,000	1,000	1,000	430	100	260	190
Lead	µg/L	-	0.02	0.024	0.029	0.01	0.012	<0.001	0.005	0.007	<0.001	0.015	0.003	0.009
Lithium	µg/L	-	3	4	6	7	4	7	6	7	9	10	10	11
Manganese	µg/L	-	160	5	52	85	26	43	65	170	740	700	500	430
Mercury	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Molybdenum	µg/L	-	0.12	0.11	0.07	0.06	0.09	0.05	0.04	0.05	0.02	0.01	0.04	0.02
Nickel	µg/L	-	0.14	0.06	0.03	0.39	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1.5	<0.005
Selenium	µg/L	-	<0.1	<0.04	0.14	0.11	0.11	0.08	0.11	0.09	<0.1	<0.1	0.24	0.15
Silver	µg/L	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.003	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Strontium	µg/L	-	60	60	110	140	110	130	100	110	150	170	170	180
Thallium	µg/L	-	0.001	0.001	0.001	0.001	0.002	0.001	<0.0003	<0.0003	0.001	<0.0003	0.002	0.001
Titanium	µg/L	-	1.1	0.8	1.1	1.4	1.7	1.6	1.4	1.7	1.9	1.7	2	1.8
Uranium	µg/L	-	0.03	0.01	0.03	0.05	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.03
Vanadium	µg/L	-	0.15	0.09	0.2	0.21	0.16	0.14	0.14	0.19	0.13	0.14	0.02	0.14
Zinc	µg/L	-	1.2	1.1	2	0.9	0.7	<0.05	0.7	0.7	0.2	0.9	2.7	2.2

Table IV-4: Compiled Water Quality Data from the Wapasu Creek Wateshed, 2007 to 2018

Wapasu Creek Stations (columns 12-Sep-07 to 17-Mar-12)

Parameter	Unit	WAC-1 12-Sep-07	WAC-1 10-Sep-08	WAC-1 20-Jul-09	WAC-1 18-Sep-09	WAC-1 28-Mar-10	WAC-1 27-Apr-10	WAC-1 28-Jul-10	WAC-1 15-Sep-10	WAC-1 29-Mar-11	WAC-1 4-May-11	WAC-1 22-Aug-11	WAC-1 16-Sep-11	WAC-1 17-Mar-12
Field Measured														
pH	-	7.2	-	6.9	-	7.5	6.9	6.9	-	7.7	7.4	7.3	-	7.9
Specific Conductivity	µS/cm	213	-	217	-	406	120	456	-	464	160	380	-	572
Temperature	°C	8.1	-	17.3	-	1.0	4.3	15.3	-	1.0	5.0	15.3	-	0.5
Dissolved oxygen	mg/L	8.8	-	7.6	-	8.2	10.2	6.9	-	6	8.6	1.9	-	3.6
Conventional Parameters														
pH	-	7.8	8.0	7.8	8.1	7.4	7.5	7.9	8.0	7.9	7.9	8.1	8.2	8.1
Specific conductivity	µS/cm	209	247	179	225	340	130	240	207	530	160	420	469	580
Hardness	mg/L	108	128	87	114	254	61	126	105	307	77	230	229	314
Total alkalinity, as CaCO3	mg/L	103	124	93	118	170	63	130	99	300	73	230	258	320
Total dissolved solids	mg/L	166	190	166	178	230	110	190	199	330	120	270	312	330
Total suspended solids	mg/L	<3.0	<3.0	<3.0	<3.0	35	3.0	9.0	<3.0	8.0	4.0	1.0	6.0	4.0
Total organic carbon	mg/L	24	31	35	35	14	16	28	31	10	17	24	24	8.4
Dissolved organic carbon	mg/L	26	11	35	33	14	15	25	31	8.8	17	23	24	7.3
Colour	TCU	110	120	178	142	51	47	91	131	27	48	68	70	14
Major Ions														
Calcium	mg/L	24	28	23	29	44	17	37	27	75	19	59	63	77
Magnesium	mg/L	8.6	11	7.0	9.3	14	5.9	11	9.3	25	6.4	18	20	28
Potassium	mg/L	1.7	<0.5	<0.5	<0.5	2.7	1.5	0.4	1.0	1.5	1.7	1.0	1.0	1.5
Sodium	mg/L	6	7	6	8	6	5	5	7	8	5	7	7	8
Bicarbonate	mg/L	126	152	113	143	210	77	160	121	360	89	270	315	390
Carbonate	mg/L	<5.0	<5.0	<5.0	<5.0	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<5.0	<0.5
Chloride	mg/L	2	2	<1	1	7	3	3	3	5	3	2	1	3
Sulphate	mg/L	3	2	1	2	2	<1	<1	2	<1	5	<1	<1	<1
Sulphide	mg/L	0.019	0.018	0.0133	0.012	0.008	0.01	0.017	0.011	0.008	<0.002	0.009	<0.002	0.010
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.1	<0.1	<0.071	<0.071	0.160	<0.003	0.011	<0.071	0.007	<0.003	0.009	<0.071	0.006
Total ammonia	mg-N/L	<0.05	<0.05	<0.05	<0.05	0.45	<0.05	0.08	<0.05	0.32	<0.05	0.05	<0.05	0.17
Total Kjeldahl nitrogen	mg-N/L	0.8	1.0	1.8	1.8	1.1	0.7	1.2	1.3	0.9	0.7	1.1	1.0	0.5
Total phosphorus	mg-P/L	0.002	0.02	0.02	0.02	0.03	0.02	0.03	-	0.06	0.02	0.03	0.04	0.05
Dissolved phosphorus	mg-P/L	0.009	0.011	0.014	0.015	0.022	0.012	0.022	-	0.059	0.011	0.009	0.023	<0.001
Biochemical oxygen demand	mg/L	<2.0	<2.0	<2.0	<2.0	4.0	<4.0	<2.0	<2.0	2.0	<2.0	<2.0	<2.0	2.3
General Organics														
Naphthenic acids	mg/L	<1.0	<1.0	1.3	0.1	<1.0	<1.0	<1.0	0.2	<1.0	<1.0	<1.0	0.4	<1.0
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.009	0.009	0.008	0.006	<0.002	<0.002	0.003	0.015	<0.002	0.004	0.004	0.007	0.006
Total recoverable hydrocarbons	mg/L	<1.0	<1.0	-	<1.0	<2.0	-	<2.0	<1.0	<2.0	<2.0	<2.0	<1.0	<2.0
Total Metals														
Aluminum	µg/L	10	20	50	70	120	20	10	20	30	30	10	10	10
Antimony	µg/L	0.02	0.02	<0.4	0.02	0.04	<0.02	0.02	<0.05	0.11	0.03	0.02	<0.05	0.02
Arsenic	µg/L	0.3	0.3	0.4	0.5	0.3	0.2	0.4	0.4	0.2	0.2	0.5	0.5	0.1
Barium	µg/L	20	20	20	20	50	10	30	20	60	20	40	50	70
Beryllium	µg/L	<0.01	<0.01	<1	0.01	0.02	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.1	<0.01
Boron	µg/L	20	20	30	30	<50	<50	<50	20	<50	20	<50	20	<50
Cadmium	µg/L	<0.006	<0.006	-	0.003	0.006	<0.005	<0.005	<0.1	0.085	0.025	0.013	<0.1	0.011
Chromium	µg/L	<0.3	<0.3	<0.8	0.08	0.3	<0.1	0.1	<0.3	0.4	0.1	0.2	<0.3	0.14
Cobalt	µg/L	0.05	0.07	<0.2	0.11	0.48	0.06	0.15	<0.1	0.34	0.08	0.23	0.24	0.26
Copper	µg/L	0.1	0.1	<1	0.7	0.5	0.1	0.2	0.1	0.4	0.3	0.3	0.2	0.2
Iron	µg/L	200	300	1,000	500	2,000	100	1,000	200	2,000	300	1,000	1,000	1,000
Lead	µg/L	<0.006	0.01	<0.1	0.03	0.59	0.03	0.02	<0.1	1.35	0.18	0.06	<0.1	0.05
Lithium	µg/L	4	5	<6	11	11	5	6	5	12	5	8	10	9
Manganese	µg/L	10	30	30	50	420	10	90	10	1,000	20	170	460	390
Mercury	µg/L	0.003	<0.0012	0.001	0.001	<0.0006	0.001	0.001	<0.05	0.001	<0.0006	0.001	0.001	0.001
Methyl mercury	µg/L	-	-	0.00029	-	0.00007	<0.00003	0.00004	-	0.00021	0.00007	<0.00003	-	0.00014
Molybdenum	µg/L	0.04	0.04	0.12	0.05	0.08	0.15	0.05	<0.1	<0.05	0.08	0.06	<0.1	<0.05
Nickel	µg/L	<0.06	0.1	1	0.2	0.9	0.3	0.5	<0.1	0.5	2.2	0.7	<0.1	0.3
Selenium	µg/L	<0.3	<0.2	<0.4	0.184	<0.04	<0.04	0.04	<0.3	0.06	<0.04	0.05	<0.3	<0.04
Silver	µg/L	<0.005	<0.005	0.096	0.0021	<0.005	<0.005	<0.005	<0.01	<0.005	<0.005	0.04	<0.01	<0.005
Strontium	µg/L	70	80	60	80	110	40	90	60	130	50	130	150	120
Thallium	µg/L	<0.003	<0.003	<0.1	0.003	0.003	0.003	<0.002	<0.1	<0.002	<0.002	<0.002	<0.1	<0.002
Titanium	µg/L	1	2	<5	2	3	<0.5	<0.5	2	<0.5	4	<0.5	1	<0.5
Uranium	µg/L	0.01	0.01	<0.1	0.03	0.16	0.01	0.04	<0.1	0.16	0.01	0.07	<0.1	0.12
Vanadium	µg/L	0.1	0.1	1.2	0.2	0.4	<0.2	<0.2	0.2	0.2	<0.2	<0.2	0.1	<0.2
Zinc	µg/L	1.1	0.6	4.7	1.2	3.4	3.5	1.1	0.8	4	17.3	2.4	1.9	6.3
Dissolved Metals														
Aluminum	µg/L	4	6	11	8	24	19	12	9	4	6	6	3	1
Antimony	µg/L	0.02	0.02	<0.4	0.02	0.05	<0.02	<0.02	<0.05	0.07	<0.02	0.02	<0.05	<0.02
Arsenic	µg/L	0.3	0.3	<0.4	0.5	0.2	0.2	0.5	0.3	0.1	0.2	0.4	0.4	0.1
Barium	µg/L	20	20	20	20	30	10	30	20	60	20	40	40	60
Beryllium	µg/L	<0.01	<0.01	<0.5	0.004	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.1	<0.01
Boron	µg/L	20	20	30	30	<50	<50	<50	20	<50	<20	<50	23	<50
Cadmium	µg/L	<0.006	<0.006	<0.1	0.002	0.01	<0.005	<0.005	<0.1	0.098	<0.005	<0.005	<0.1	0.007
Chromium	µg/L	<0.3	<0.3	<0.4	0.1	0.2	<0.1	<0.1	<0.3	0.1	<0.1	0.1	<0.3	<0.1
Cobalt	µg/L	0.04	0.05	<0.1	0.06	0.43	0.06	0.14	<0.1	0.31	0.05	0.18	0.17	0.24
Copper	µg/L	0.1	0.1	<0.6	0.7	1	0.2	0.2	0.1	5.2	2.4	0.1	0.2	0.3
Iron	µg/L	110	210	310	260	490	160	1,000	150	50	160	310	210	30
Lead	µg/L	<0.006	<0.006	<0.1	0.01	0.15	0.05	0.02	<0.1	2.1	0.03	0.04	<0.1	0.04
Lithium	µg/L	4	5	5	11	14	5	6	5	14	5	8	10	9
Manganese	µg/L	2	2	16	4	280	10	87	3	500	5	110	350	360
Mercury	µg/L	<0.05	<0.05	<0.0006	<0.05	<0.0006	0.001	<0.0006	<0.05	<0.0006	<0.0006	<0.0006	<0.05	0.001
Molybdenum	µg/L	0.05	0.04	<0.1	0.05	0.18	0.07	<0.05	<0.1	<0.05	0.08	0.06	<0.1	<0.05
Nickel	µg/L	<0.06	<0.06	0.7	0.2	0.8	0.4	0.5	<0.1	0.4	0.6	0.9	<0.1	0.2
Selenium	µg/L	<0.3	<0.2	<0.4	0.18	0.05	<0.04	<0.04	<0.3	0.04	<0.04	0.06	<0.3	<0.04
Silver	µg/L	<0.005	<0.005	0.005	<0.005	0.01	<0.005	<0.005	<0.01	<0.005	<0.005	<0.005	<0.01	<0.005
Strontium	µg/L	70	80	70	80	80	40	80	60	120	50	130	150	120
Thallium	µg/L	<0.003	<0.003	<0.05	0.003	0.003	<0.002	<0.002	<0.1	<0.002	<0.002	<0.002	<0.1	<0.002
Titanium	µg/L	0.8	1.5	0.6	1.2	1	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	1	<0.5
Uranium	µg/L	0.01	0.01	<0.1	0.03	0.15	0.01	0.04	<0.1	0.15	0.01	0.06	<0.1	0.12
Vanadium	µg/L	0.1	0.1	0.2	0.1	<0.2	<0.2	<0.2	0.1	<0.2	<0.2	<0.2	<0.1	<0.2
Zinc	µg/L	1.1	0.6	1.7	1.2	3.1	13	0.3	0.8	3.6	6.1	4.3	1.6	5.5

Wapasu Creek Stations (columns 8-May-12 to 20-Mar-16)

Parameter	Unit	WAC-1 8-May-12	WAC-1 17-Jul-12	WAC-1 8-Sep-12	WAC-1 14-Mar-13	WAC-1 16-Apr-13	WAC-1 22-Jul-13	WAC-1 13-Sep-13	WAC-1 18-Mar-14	WAC-1 7-May-14	WAC-1 1-Sep-14	WAC-1 6-Sep-14	WAC-1 15-Mar-15	WAC-1 24-May-15	WAC-1 19-Jul-15	WAC-1 20-Mar-16
Field Measured																
pH	-	7.1	-	-	7.4	6.8	7.1	-	7.3	7.6	7.3	-	7.3	7.4	7.9	7.2
Specific Conductivity	µS/cm	173	218	-	407	159	170	-	554	453	273	-	543	202	290	540
Temperature	°C	9.0	18.6	-	0.5	0.1	15.8	-	0.1	1.4	11.1	-	-0.1	15.9	17.5	0.1
Dissolved oxygen	mg/L	10.6	4.6	-	11.1	12.4	6.9	-	10.6	11.4	9.4	-	6.2	8.0	7.1	11.1
Conventional Parameters																
pH	-	8.0	8.0	7.9	7.6	7.7	7.8	8.0	7.8	7.7	7.7	8.0	7.9	7.8	7.8	8.0
Specific conductivity	µS/cm	200	280	246	400	360	260	377	570	190	290	295	580	200	300	540
Hardness	mg/L	95	150	107	183	178	133	223	309	80.2	138	156	285	85.7	153	263
Total alkalinity, as CaCO3	mg/L	90	140	121	210	180	130	200	300	65	140	149	280	77	150	270
Total dissolved solids	mg/L	140	250	206	270	250	200	288	330	140	200	217	330	150	210	310
Total suspended solids	mg/L	1.0	<1.0	3.0	<1.0	4.0	1.3	3	2	2	1.3	<3	<1.0	<1.0	1.3	<1.0
Total organic carbon	mg/L	20	37	5.9	28	24	25	27.5	8.1	13	24	26.4	16	18	26	16
Dissolved organic carbon	mg/L	18	37	5.7	27	24	27	27.3	8.2	13	25	26.3	15	18	25	16
Colour	TCU	50	130	105	92	86	100	125	15	35	99	-	38	72	96	48
Major Ions																
Calcium	mg/L	24	36	28	50	50	35	60.3	79.1	20.1	38.5	181	75.6	22	39.7	68
Magnesium	mg/L	7.9	12	9.0	18	16	11	17.5	25.6	6.82	12.5	13.8	24.9	7.47	12.9	22.7
Potassium	mg/L	3.4	0.78	1.6	1.5	1.6	0.29	1.07	1.54	2.15	0.768	0.87	1.68	1.56	0.757	1.77
Sodium	mg/L	7	9	9	11	10	6	8	7.23	5.47	7.4	8.6	8.59	8.01	8.07	9.32
Bicarbonate	mg/L	110	170	148	250	220	160	244	360	79	170	181	350	94	180	330
Carbonate	mg/L	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	5	<0.50	<0.50	<0.50	<5	<0.50	<0.50	<0.50	<0.50
Chloride	mg/L	7	6	4	4	3	6	3.39	1.7	12	4.8	4.02	5.2	8.1	6.8	7
Sulphate	mg/L	5	<1	1	1	1	<1.0	0.61	3.1	9	<1.0	0.59	<1.0	2.9	<1.0	<1.0
Sulphide	mg/L	0.009	0.011	0.004	<0.002	0.007	<0.002	0.0102	<0.0020	<0.0020	0.003	0.0096	<0.0019	<0.0019	0.0074	0.0055
Nutrients and Biological Indicators																
Nitrate + nitrite	mg-N/L	0.004	0.014	0.071	0.019	0.130	<0.003	0.071	0.025	<0.010	<0.010	<0.054	0.017	<0.010	0.024	0.034
Total ammonia	mg-N/L	<0.05	<0.05	0.05	0.48	0.52	<0.05	0.05	0.17	0.054	0.072	<0.05	0.53	<0.050	0.086	0.67
Total Kjeldahl nitrogen	mg-N/L	0.9	1.7	1.0	1.3	0.9	0.9	0.9	0.33	0.5	0.72	0.62	1.2	0.61	0.79	1.1
Total phosphorus	mg-P/L	0.01	0.04	0.03	0.05	0.09	0.03	0.0343	0.02	0.016	0.015	0.017	0.015	0.013	0.03	0.036
Dissolved phosphorus	mg-P/L	0.009	0.03	0.017	0.03	0.044	0.018	0.0267	<0.0010	0.0075	0.015	0.0108	0.006	0.006	0.021	0.017
Biochemical oxygen demand	mg/L	<2.0	<2.0	2.0	<2.0	2.5	<2.0	2	<2.0	<2.0	<2.0	<2	2.8	<2.0	<2.0	<2.0
General Organics																
Naphthenic acids	mg/L	<1.0	<1.0	0.1	<1.0	<1.0	<1.0	0.41	<1.0	<1.0	<1.0	0.81	<1.0	<1.0	<1.0	<1.0
Phenol[(a)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(b)]	mg/L	0.003	0.008	0.012	0.007	0.006	0.006	0.0084	0.0035	0.0035	0.0072	0.0039	0.0022	0.0031	<0.0020	<0.0020
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<1.0	<2.0	<2.0	<2.0	-	<2.0	<2.0	<2.0	-	<2.0	<2.0	<2.0	2.5
Total Metals																
Aluminum	µg/L	20	30	50	20	30	40	25	5.98	15.6	10.5	9.6	45.9	16.1	26.3	10.3
Antimony	µg/L	<0.02	0.02	0.05	0.03	0.08	<0.02	0.05	0.026	0.02	<0.020	0.015	0.034	<0.020	<0.050	<0.020
Arsenic	µg/L	0.2	0.6	0.5	0.4	0.4	0.5	0.514	0.097	0.195	0.403	0.337	0.323	0.204	0.47	0.228
Barium	µg/L	20	30	30	40	40	30	38	66	14.8	28.9	27.3	77.5	17	31.2	60.9
Beryllium	µg/L	<0.01	0.01	0.1	<0.01	<0.01	<0.01	0.1	<0.010	<0.010	<0.010	<0.008	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	<50	30	<50	<50	<50	26	<50	<50	21	24.7	33	25	<50	34
Cadmium	µg/L	0.005	0.005	0.01	0.026	0.018	<0.005	0.01	<0.0050	0.005	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	<0.1	0.11	0.3	0.13	0.19	<0.1	0.3	0.13	<0.10	<0.10	0.12	0.17	<0.10	<0.50	0.11
Cobalt	µg/L	0.09	0.18	0.18	0.52	0.52	0.17	0.213	0.21	0.067	0.14	0.069	1.17	0.075	0.217	0.542
Copper	µg/L	0.2	0.1	0.1	0.3	1	0.1	0.68	0.544	0.296	0.097	0.06	0.303	0.053	1.44	0.105
Iron	µg/L	300	1,000	1,000	3,000	3,000	1,000	979	839	189	739	462	3,440	188	762	1,970
Lead	µg/L	0.04	0.04	0.1	0.08	0.19	0.07	0.1	0.015	0.069	0.015	0.008	0.0623	0.016	<0.050	0.012
Lithium	µg/L	6	8	6	9	8	8	8.36	9.8	9.58	9.03	6.79	10.2	6.93	7.72	10.9
Manganese	µg/L	20	60	170	1,000	1,000	80	161	482	17	78	42	2,020	24	108	888
Mercury	µg/L	0.001	<0.0006	0.003	<0.0006	<0.001	0.001	0.00095	0.000479	0.00159	0.00131	0.00095	0.0011	0.00131	0.00156	0.00058
Methyl mercury	µg/L	0.00009	0.00052	-	0.00035	0.0003	0.0004	-	0.00009	<0.00008	0.00023	-	0.0003	0.00023	0.00042	0.00015
Molybdenum	µg/L	0.09	0.1	0.1	<0.05	0.06	0.07	0.1	0.05	0.092	<0.050	0.024	0.057	<0.050	0.078	<0.050
Nickel	µg/L	0.4	0.6	0.1	0.5	1	0.5	0.254	0.288	0.362	0.484	<0.008	0.581	0.402	0.78	0.325
Selenium	µg/L	<0.04	<0.04	0.3	<0.04	<0.04	0.05	0.3	<0.040	<0.040	<0.040	0.09	<0.040	<0.040	0.044	<0.040
Silver	µg/L	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	0.01	<0.0050	<0.0050	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	60	100	80	120	110	100	126	123	52.6	100	90.4	139	53.9	100	128
Thallium	µg/L	<0.002	0.002	0.1	<0.002	<0.002	0.002	0.1	<0.0020	0.002	<0.0020	0.0012	0.0026	<0.0020	<0.0020	<0.0020
Titanium	µg/L	1	1	2	1	1	1	2.44	<0.50	0.51	<0.50	1.19	1.13	<0.50	<5.0	<0.50
Uranium	µg/L	0.01	0.02	0.1	0.06	0.05	0.02	0.1	0.227	0.01	0.026	0.033	0.193	0.009	0.0368	0.134
Vanadium	µg/L	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	0.164	<0.20	<0.20	<0.20	0.13	<0.20	<0.20	<0.50	<0.20
Zinc	µg/L	1	1	0.7	5.7	7.4	1.3	1.32	1.48	2.28	3.62	0.4	5.33	2.43	4	1.36
Dissolved Metals																
Aluminum	µg/L	6	9	5	10	17	7	7.08	1.83	4.2	7.36	3.5	3.17	6.57	6.22	3.39
Antimony	µg/L	<0.02	0.03	0.05	0.02	0.05	<0.02	0.05	<0.020	<0.020	<0.020	0.015	<0.020	<0.020	<0.020	<0.020
Arsenic	µg/L	0.2	0.6	0.4	0.3	0.3	0.4	0.466	0.106	0.176	0.363	0.284	0.21	0.234	0.417	0.174
Barium	µg/L	20	30	20	40	40	20	35.1	62.5	14.1	27.3	22.8	62.9	19.1	29.4	55.9
Beryllium	µg/L	<0.01	0.023	0.1	<0.01	<0.01	<0.01	0.1	<0.010	<0.010	<0.010	<0.009	<0.010	<0.010	<0.010	<0.010
Boron	µg/L	<50	<50	25	<50	<50	<50	26	<50	<50	22	22.5	28	30	14	32
Cadmium	µg/L	0.007	<0.005	0.01	0.025	0.013	<0.005	0.01	<0.0050	<0.0050	<0.0050	<0.002	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	µg/L	<0.1	<0.1	0.3	<0.1	0.2	<0.1	0.3	<0.10	<0.10	<0.10	0.1	<0.10	<0.10	<0.10	<0.10
Cobalt	µg/L	0.08	0.14	0.1	0.51	0.5	0.09	0.198	0.197	0.037	0.125	0.042	0.737	0.037	0.118	0.515
Copper	µg/L	0.6	0.1	0.1	0.4	0.7	0.1	0.653	0.064	0.076	0.209	<0.08	0.084	0.153	0.056	<0.050
Iron	µg/L	170	1,000	240	2,000	2,000	490	683	52	77	575	267	582	97	448	474
Lead	µg/L	0.02	0.02	0.1	0.04	0.13	0.01	0.1	<0.0050	<0.0050	0.014	0.005	<0.0050	<0.0050	<0.0050	<0.0050
Lithium	µg/L	6	8	7	9	8	8	8.27	9.5	9.27	8	5.93	10	8.07	8.76	10.5
Manganese	µg/L	9	23	28	580	610	25	113	458	1.81	40.2	8.96	1,520	0.583	28.6	893
Mercury	µg/L	<0.0006	0.002	0.05	<0.0006	<0.001	0.002	0.05	0.000349	0.00093	0.00113	<0.009	0.00041	0.00101	0.00117	-
Molybdenum	µg/L	0.11	0.1	0.1	<0.05	<0.05	0.06	0.1	0.106	0.146	<0.050	0.024	<0.050	0.063	<0.050	<0.050
Nickel	µg/L	0.4	0.6	0.1	0.5	0.7	0.4	0.227	0.295	0.341	0.414	<0.006	0.339	0.404	0.483	0.328
Selenium	µg/L	<0.04	0.05	0.3	0.05	0.05	<0.04	0.3	<0.040	<0.040	<0.040	0.06	<0.040	<0.040	<0.040	<0.040
Silver	µg/L	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	0.01	<0.0050	<0.0050	<0.0050	<0.001	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	µg/L	60	100	80	120	110	90	124	115	51.8	94.2	79.1	132	64	101	131
Thallium	µg/L	<0.002	<0.002	0.1	<0.002	0.002	<0.002	0.1	<0.0020	<0.0020	<0.0020	0.0004	0.0043	<0.0020	<0.0020	0.002
Titanium	µg/L	<0.5	<0.5	1.4	<0.5	<0.5	<0.5	1.97	<0.50	<0.50	<0.50	0.98	<0.50	<0.50	<0.50	<0.50
Uranium	µg/L	0.01	0.01	0.1	0.05	0.05	0.01	0.1	0.214	0.007	0.025	0.026	0.182	0.008	0.0281	0.133
Vanadium	µg/L	<0.2	<0.2	0.1	<0.2	<0.2	<0.2	0.135	<0.20	<0.20	<0.20	0.09	<0.20	<0.20	<0.20	<0.20
Zinc	µg/L	1	1.6	0.5	5.1	4.2	0.8	1.07	0.74	0.89	0.83	0.41	0.42	0.24	0.26	0.62

(a) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(b) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
- = not applicable or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre.

Table IV-4: Compiled Water Quality Data from the Wapasu Creek Wateshed, 2007 to 2018

Parameter	Unit	Wapasu Creek Stations							
		WAC-1	WAC-1	WAC-1	WAC-1	WAC-1	WAC-1	WAC-1	WAC-1
		20-Aug-16	1-Apr-17	16-May-17	29-Aug-17	10-Mar-18	14-May-18	21-Aug-18	16-Oct-18
Field Measured									
pH	-	6.4	6.9	-	7.5	7.0	7.2	7.0	7.0
Specific Conductivity	μS/cm	373	245	-	499	468	209	364	271
Temperature	°C	12.3	-3.2	-	12.4	0.1	11.1	15.8	1.0
Dissolved oxygen	mg/L	8.6	10.1	-	6.9	4.3	9.0	1.5	11.7
Conventional Parameters									
pH	-	7.9	7.5	8.1	8.1	8.0	7.9	8.1	7.8
Specific conductivity	μS/cm	380	260	180	510	570	230	500	310
Hardness	mg/L	191	130	73	280	300	110	280	150
Total alkalinity, as CaCO3	mg/L	210	140	76	260	290	87	260	140
Total dissolved solids	mg/L	260	160	120	220	320	170	300	190
Total suspended solids	mg/L	4.8	2.5	1.7	<1.0	1.7	<1.0	<1.0	<1.0
Total organic carbon	mg/L	24	18	17	14	11	20	18	18
Dissolved organic carbon	mg/L	24	17	16	14	9.4	19	17	21
Colour	TCU	83	80	52	33	21	79	17	46
Major Ions									
Calcium	mg/L	51.5	33	18	72	84	27	68	35
Magnesium	mg/L	15.3	11	7	24	28	9.4	23	12
Potassium	mg/L	0.893	2.2	1.2	1.4	1.5	2.1	1.3	1
Sodium	mg/L	9.23	7	6.3	8.8	8.7	7.9	8.2	8.9
Bicarbonate	mg/L	260	170	93	320	350	110	320	170
Carbonate	mg/L	<0.50	<0.50	<0.50	<0.50	<1.0	<1.0	<1.0	<1.0
Chloride	mg/L	6.4	7.8	6	3.6	3	7.5	4.8	10
Sulphate	mg/L	<1.0	<1.0	<1.0	<1.0	4.1	17	<1.0	<1.0
Sulphide	mg/L	0.016	0.0027	0.0043	0.0051	<0.0019	0.0043	0.008	0.01
Nutrients and Biological Indicators									
Nitrate + nitrite	mg-N/L	<0.020	0.041	<0.010	<0.014	<0.014	<0.014	<0.014	<0.014
Total ammonia	mg-N/L	<0.050	0.54	<0.015	0.016	0.36	0.02	0.023	<0.015
Total Kjeldahl nitrogen	mg-N/L	0.89	1.1	0.58	0.43	0.69	0.57	0.57	0.66
Total phosphorus	mg-P/L	0.025	0.056	0.012	0.014	0.015	0.0083	0.015	0.011
Dissolved phosphorus	mg-P/L	0.023	0.011	0.82	0.0048	<0.0010	0.007	0.0095	0.0038
Biochemical oxygen demand	mg/L	<2.0	2.6	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
General Organics									
Naphthenic acids	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Phenol[a]	mg/L	-	0.0033	< 0.0020	< 0.0020	< 0.0020	0.0051	0.0051	< 0.0020
Total phenolics[b]	mg/L	<0.0020	-	-	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Metals									
Aluminum	μg/L	31.3	34	27	3.8	4.3	7.8	7	8.4
Antimony	μg/L	0.022	<0.020	0.036	<0.020	<0.020	<0.020	<0.020	<0.020
Arsenic	μg/L	0.39	0.23	0.2	0.2	0.13	0.24	0.26	0.23
Barium	μg/L	37.5	29	16	48	65	21	42	21
Beryllium	μg/L	0.011	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	μg/L	24	16	20	36	43	28	33	16
Cadmium	μg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	μg/L	0.13	<0.10	<0.10	<0.10	0.1	<0.10	<0.10	<0.10
Cobalt	μg/L	0.225	0.41	0.067	0.11	0.38	0.07	0.17	0.082
Copper	μg/L	0.55	0.095	<0.10	0.056	0.1	<0.10	<0.10	<0.10
Iron	μg/L	739	2,300	210	320	1,300	170	350	320
Lead	μg/L	0.026	0.038	0.025	0.0087	0.0065	<0.020	<0.020	<0.020
Lithium	μg/L	8.16	6.3	5.8	9.4	8.9	7	8.9	8.3
Manganese	μg/L	162	580	28	91	690	15	200	63
Mercury	μg/L	0.00092	0.00139	0.00099	0.00058	0.00034	0.00106	0.00066	0.00047
Methyl mercury	μg/L	0.00018	0.00021	0.00010	0.0001	0.00012	0.00013	0.00012	<0.00008
Molybdenum	μg/L	<0.050	0.073	0.056	<0.050	<0.050	0.075	<0.050	<0.050
Nickel	μg/L	0.44	0.34	0.51	0.25	0.23	0.35	0.34	0.27
Selenium	μg/L	0.041	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040
Silver	μg/L	<0.010	<0.0050	<0.010	<0.0050	<0.0050	<0.010	<0.010	<0.010
Strontium	μg/L	110	76	53	120	130	74	130	81
Thallium	μg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	μg/L	<2.0	0.99	2.5	<0.50	<0.50	<2.0	<2.0	<2.0
Uranium	μg/L	0.055	0.029	0.0079	0.14	0.15	0.0096	0.13	0.019
Vanadium	μg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Zinc	μg/L	<1.0	1.7	<1.0	0.31	1.5	<1.0	<1.0	<1.0
Dissolved Metals									
Aluminum	μg/L	3.58	14	3	1.2	1.1	3.7	9.8	2.8
Antimony	μg/L	<0.020	<0.020	0.024	<0.020	<0.020	0.02	0.063	<0.020
Arsenic	μg/L	0.393	0.23	0.16	0.19	0.096	0.24	0.29	0.2
Barium	μg/L	34.1	30	13	47	62	18	46	22
Beryllium	μg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Boron	μg/L	26	17	17	37	40	26	37	16
Cadmium	μg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Chromium	μg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cobalt	μg/L	0.122	0.4	0.035	0.095	0.37	0.057	0.16	0.06
Copper	μg/L	0.054	0.13	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Iron	μg/L	283	2,400	66	54	52	100	100	170
Lead	μg/L	<0.0050	0.025	<0.0050	<0.0050	<0.0050	<0.0050	0.0061	<0.0050
Lithium	μg/L	8.11	6.8	5.1	9.3	9.2	6.8	9.3	8.1
Manganese	μg/L	3.06	590	0.59	59	720	5.6	88	31
Mercury	μg/L	0.00073	0.00073	0.00058	0.00043	0.00014	0.00052	0.00034	0.00039
Molybdenum	μg/L	<0.050	0.073	0.053	<0.050	<0.050	0.063	<0.050	0.055
Nickel	μg/L	0.395	0.37	0.21	0.29	0.2	0.29	0.32	0.28
Selenium	μg/L	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.042
Silver	μg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Strontium	μg/L	117	76	47	120	120	68	150	82
Thallium	μg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Titanium	μg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Uranium	μg/L	0.052	0.025	0.0064	0.14	0.16	0.008	0.14	0.02
Vanadium	μg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Zinc	μg/L	0.29	1.7	0.19	0.17	0.91	0.29	0.19	0.56

APPENDIX V

Water Quality Seasonal Summary Statistics from 2006 to 2018 Compared to Guidelines

Table V-1: Baseline Phase Seasonal Water Quality Data from the Firebag River Watershed Compared to Guidelines, 2006 to 2010

Guidelines: GOA (2018) Guidelines for the Protection of: / Health Canada (2017)

Parameter	Unit	Aquatic Life: Acute	Aquatic Life: Chronic	Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO
Field Measured						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11
Specific conductivity	µS/cm	-	-	-	-	-
Temperature	°C	-	-	-	-	15
Dissolved oxygen	mg/L	5.0	6.5	-	-	-
Conventional Parameters						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11
Specific conductivity	µS/cm	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500
Total suspended solids	mg/L	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-
Colour	TCU	-	-	-	-	15
Major Ions						
Bicarbonate	mg/L	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-
Carbonate	mg/L	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250
Magnesium	mg/L	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200
Sulphate	mg/L	-	218 to 429[b, c]	1,000	-	500
Sulphide	mg/L	-	0.0023 to 0.029[d]	-	-	0.050
Nutrients and Biological Indicators						
Nitrate + nitrite	mg-N/L	-	-	100	-	-
Total ammonia	mg-N/L	-	0.20[e]	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-
General Organics						
Naphthenic acids	mg/L	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-
Total Metals						
Aluminum	µg/L	-	-	5,000	-	-
Antimony	µg/L	-	-	-	6.0	-
Arsenic	µg/L	-	5.0	25	10	-
Barium	µg/L	-	-	-	1,000	-
Beryllium	µg/L	-	-	100	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-
Cadmium	µg/L	1.3 to 7.7[b]	0.11 to 0.37[b]	80	5.0	-
Chromium	µg/L	-	1.0[h]	50	50[h]	-
Cobalt	µg/L	-	0.84 to 1.8[b]	1,000	-	-
Copper	µg/L	10 to 79[b]	7.0[b]	500	-	1,000
Iron	µg/L	-	-	-	-	300
Lead	µg/L	-	1.8 to 7.0[b]	100	10	-
Lithium	µg/L	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50
Mercury	µg/L	0.013	0.0050	3.0	1.0	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-
Molybdenum	µg/L	-	73	500	-	-
Nickel	µg/L	317 to 1,859[b]	35 to 207[b]	1,000	-	-
Selenium	µg/L	-	2.0	50	50	-
Silver	µg/L	-	0.25	-	-	-
Strontium	µg/L	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-
Titanium	µg/L	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-
Vanadium	µg/L	-	-	100	-	-
Zinc	µg/L	-	30	50,000	-	5,000
Dissolved Metals						
Aluminum	µg/L	100[d]	50[d]	-	-	-
Antimony	µg/L	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-
Barium	µg/L	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-
Boron	µg/L	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-
Copper	µg/L	-	-	-	-	-
Iron	µg/L	-	300	-	-	-
Lead	µg/L	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-
Silver	µg/L	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-

Seasonal Summary – Winter

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.5	7.6	8.3	7.0	8.3	0.54	0	6	-	-	-	-	-
Specific conductivity	286	285	423	174	466	102	0	6	-	-	-	-	-
Temperature	0.20	0.42	1.1	0	1.2	0.51	0	6	-	-	-	-	-
Dissolved oxygen	**3.4[A, C]**	**5.3[C]**	14	**1.0[A, C]**	16	5.7	0	6	50	67	-	-	-
Conventional Parameters													
pH	7.9	7.8	8.2	7.1	8.2	0.43	0	6	-	-	-	-	-
Specific conductivity	312	364	645	190	720	192	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	166	216	443	95	509	153	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	167	200	373	97	420	117	0	6	-	-	-	-	-
Total dissolved solids	196	208	359	110	410	106	0	6	-	-	-	-	-
Total suspended solids	4.5	-	167	<3.0	220	-	2	6	-	-	-	-	-
Total organic carbon	14	14	24	5.4	27	7.2	0	6	-	-	-	-	-
Dissolved organic carbon	14	14	23	4.9	24	6.4	0	6	-	-	-	-	-
Colour	**49[S]**	**45[S]**	**58[S]**	**28[S]**	**59[S]**	12	0	6	-	-	-	-	100
Major Ions													
Bicarbonate	203	244	460	118	520	147	0	6	-	-	-	-	-
Calcium	41	53	104	25	119	35	0	6	-	-	-	-	-
Carbonate	<5.0	-	<5.0	<0.5	<5.0	-	6	6	-	-	-	-	-
Chloride	1.0	1.3	2.0	1.0	2.0	0.52	0	6	-	-	-	-	-
Magnesium	16	17	30	8.0	33	9.0	0	6	-	-	-	-	-
Potassium	0.95	-	2.3	<0.5	2.6	-	2	6	-	-	-	-	-
Sodium	3.0	3.0	4.0	2.0	4.0	0.89	0	6	-	-	-	-	-
Sulphate	1.0	-	2.0	<1.0	2.0	-	3	6	-	-	-	-	-
Sulphide	**0.0080[C]**	**0.015[C]**	**0.047[C]**	<0.002	**0.058[C, S]**	0.021	1	6	-	50	-	-	17
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.1	-	0.17	<0.003	0.17	-	4	6	-	-	-	-	-
Total ammonia	<0.05	-	1.2	<0.05	1.5	-	4	6	-	-	-	-	-
Total Kjeldahl nitrogen	0.50	1.0	2.8	0.40	3.5	1.2	0	6	-	-	-	-	-
Total nitrogen (calculated)	0.59	1.0	2.8	0.40	3.5	1.2	0	6	-	-	-	-	-
Total phosphorus	0.025	0.025	0.045	0.010	0.050	0.015	0	6	-	-	-	-	-
Dissolved phosphorus	0.013	0.016	0.026	0.0090	0.028	0.0076	0	6	-	-	-	-	-
Biochemical oxygen demand	<3.0	-	12	<2.0	12	-	5	6	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	6	6	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0040[W]**	-	**0.0048[C, W]**	<0.002	**0.0050[C, W]**	-	3	6	-	17	50	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<1.0	<2.0	-	6	6	-	-	-	-	-
Total Metals													
Aluminum	30	-	758	10	1,000	-	2	6	-	-	-	-	-
Antimony	0.10	-	<0.4	0.040	<0.4	-	3	6	-	-	-	-	-
Arsenic	<0.4	-	0.96	0.16	0.96	-	3	6	-	-	-	-	-
Barium	30	48	116	21	141	46	0	6	-	-	-	-	-
Beryllium	0.11	-	<1.0	<0.01	<1.0	-	5	6	-	-	-	-	-
Boron	30	-	60	<20	60	-	4	6	-	-	-	-	-
Cadmium	0.048	0.11	0.24	0.031	0.26	0.13	0	3	-	-	-	-	-
Chromium	<0.8	-	**1.3[C]**	<0.1	**1.3[C]**	-	4	6	-	17	-	-	-
Cobalt	<0.2	-	1.3	0.061	1.3	-	3	6	-	-	-	-	-
Copper	0.80	-	<1.0	0.50	<1.0	-	3	6	-	-	-	-	-
Iron	**1,000[S]**	**1,743[S]**	**5,500[S]**	120	**7,000[S]**	2,604	0	6	-	-	-	-	83
Lead	0.13	-	1.7	<0.1	1.9	-	3	6	-	-	-	-	-
Lithium	7.0	-	23	4.0	24	-	2	6	-	-	-	-	-
Manganese	34	**234[S]**	**821[S]**	24	**1,000[S]**	389	0	6	-	-	-	-	33
Mercury	<0.0006	-	0.0033	<0.0006	0.0037	-	3	5	-	-	-	-	-
Methyl mercury	0.000030	-	0.000050	<0.00003	<0.00008	-	4	6	-	-	-	-	-
Molybdenum	0.20	-	0.22	<0.05	0.22	-	3	6	-	-	-	-	-
Nickel	0.85	1.1	2.4	0.30	2.8	0.89	0	6	-	-	-	-	-
Selenium	<0.4	-	1.4	<0.04	1.4	-	4	6	-	-	-	-	-
Silver	0.030	-	0.21	<0.005	0.24	-	2	6	-	-	-	-	-
Strontium	70	133	308	50	340	118	0	6	-	-	-	-	-
Thallium	0.0060	-	<0.1	<0.002	<0.1	-	5	6	-	-	-	-	-
Titanium	<5.0	-	7.9	<0.5	7.9	-	4	6	-	-	-	-	-
Uranium	0.090	-	<0.1	0.0090	<0.1	-	3	6	-	-	-	-	-
Vanadium	<0.2	-	4.0	<0.2	4.0	-	5	6	-	-	-	-	-
Zinc	<4.0	-	8.8	0.050	10	-	3	6	-	-	-	-	-
Dissolved Metals													
Aluminum	7.0	-	<10	4.0	<10	-	3	6	-	-	-	-	-
Antimony	0.040	-	<0.4	<0.02	<0.4	-	5	6	-	-	-	-	-
Arsenic	<0.4	-	0.73	0.11	0.73	-	3	6	-	-	-	-	-
Barium	30	40	78	20	90	25	0	6	-	-	-	-	-
Beryllium	<0.5	-	<0.5	<0.01	<0.5	-	6	6	-	-	-	-	-
Boron	34	-	<50	5.0	<50	-	3	6	-	-	-	-	-
Cadmium	0.011	-	<0.1	0.0070	<0.1	-	3	6	-	-	-	-	-
Chromium	0.10	-	0.60	<0.1	0.60	-	4	6	-	-	-	-	-
Cobalt	<0.1	-	0.27	0.032	0.33	-	2	6	-	-	-	-	-
Copper	0.23	-	<0.6	0.090	<0.6	-	3	6	-	-	-	-	-
Iron	300	**483[C]**	**1,000[C]**	100	**1,000[C]**	412	0	6	-	50	-	-	-
Lead	<0.1	-	0.21	0.030	0.21	-	3	6	-	-	-	-	-
Lithium	5.5	10	23	2.0	24	9.6	0	6	-	-	-	-	-
Manganese	30	180	608	14	720	283	0	6	-	-	-	-	-
Mercury	<0.0006	-	0.00098	<0.0006	0.0010	-	4	6	-	-	-	-	-
Molybdenum	0.10	-	0.18	<0.05	0.20	-	3	6	-	-	-	-	-
Nickel	0.65	0.55	0.88	0.10	0.90	0.33	0	6	-	-	-	-	-
Selenium	0.060	-	<0.4	<0.04	<0.4	-	5	6	-	-	-	-	-
Silver	<0.005	-	0.012	<0.005	0.012	-	3	4	-	-	-	-	-
Strontium	70	128	285	50	310	107	0	6	-	-	-	-	-
Thallium	<0.05	-	<0.05	<0.002	<0.05	-	6	6	-	-	-	-	-
Titanium	0.50	-	0.70	<0.5	0.70	-	3	6	-	-	-	-	-
Uranium	<0.1	-	0.10	0.010	0.10	-	3	6	-	-	-	-	-
Vanadium	<0.2	-	0.30	<0.1	0.30	-	5	6	-	-	-	-	-
Zinc	1.0	-	5.3	<1.0	6.0	-	3	6	-	-	-	-	-

Seasonal Summary – Spring

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.4	7.3	7.9	**6.6[S]**	7.9	0.49	0	6	-	-	-	-	33
Specific conductivity	194	208	362	104	406	109	0	6	-	-	-	-	-
Temperature	11	9.3	14	0.80	14	5.3	0	6	-	-	-	-	-
Dissolved oxygen	10	9.6	11	6.8	12	1.8	0	5	-	-	-	-	-
Conventional Parameters													
pH	8.1	8.0	8.2	7.8	8.2	0.16	0	9	-	-	-	-	-
Specific conductivity	240	268	464	130	526	126	0	9	-	-	-	-	-
Hardness, as $CaCO_3$	127	142	249	63	279	70	0	9	-	-	-	-	-
Total alkalinity, as $CaCO_3$	130	141	243	65	272	67	0	9	-	-	-	-	-
Total dissolved solids	160	173	299	70	330	82	0	9	-	-	-	-	-
Total suspended solids	<3.0	-	9.8	<3.0	11	-	5	9	-	-	-	-	-
Total organic carbon	14	16	25	11	25	5.6	0	9	-	-	-	-	-
Dissolved organic carbon	14	15	22	10	24	4.6	0	9	-	-	-	-	-
Colour	**56[S]**	**56[S]**	**68[S]**	**39[S]**	**70[S]**	9.0	0	9	-	-	-	-	100
Major Ions													
Bicarbonate	150	171	296	79	332	83	0	9	-	-	-	-	-
Calcium	31	37	65	17	75	18	0	9	-	-	-	-	-
Carbonate	<5.0	-	<5.0	<0.5	<5.0	-	9	9	-	-	-	-	-
Chloride	2.0	1.7	3.2	<1.0	4.0	1.0	1	9	-	-	-	-	-
Magnesium	12	12	21	5.2	22	5.9	0	9	-	-	-	-	-
Potassium	1.3	1.4	3.1	<0.5	3.7	1.1	2	9	-	-	-	-	-
Sodium	3.0	3.1	5.4	1.0	7.0	1.6	0	9	-	-	-	-	-
Sulphate	3.0	3.9	11	<1.0	13	4.1	2	9	-	-	-	-	-
Sulphide	0.0050	0.0043	0.0062	<0.003	**0.0070[C]**	0.0018	2	9	-	33	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.1	-	<0.1	0.0060	<0.1	-	7	9	-	-	-	-	-
Total ammonia	<0.05	-	<0.05	<0.05	<0.05	-	9	9	-	-	-	-	-
Total Kjeldahl nitrogen	0.50	0.64	1.1	0.40	1.3	0.31	0	9	-	-	-	-	-
Total nitrogen (calculated)	0.50	0.65	1.1	0.40	1.3	0.31	0	9	-	-	-	-	-
Total phosphorus	0.050	0.051	0.11	0.010	0.12	0.039	0	9	-	-	-	-	-
Dissolved phosphorus	0.026	0.026	0.046	0.012	0.047	0.014	0	9	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	7.0	<2.0	7.0	-	7	9	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	9	9	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0040[W]**	-	**0.0080[C, W]**	<0.001	**0.0080[C, W]**	-	3	9	-	44	56	-	-
Total recoverable hydrocarbons	1.0	-	<2.0	<1.0	<2.0	-	6	8	-	-	-	-	-
Total Metals													
Aluminum	30	44	102	<20	130	36	2	9	-	-	-	-	-
Antimony	0.70	0.85	2.0	<0.02	2.0	0.73	1	9	-	-	-	-	-
Arsenic	<0.4	-	0.40	0.18	0.40	-	6	9	-	-	-	-	-
Barium	29	31	51	18	63	13	0	9	-	-	-	-	-
Beryllium	<1.0	-	<1.0	<0.01	<1.0	-	9	9	-	-	-	-	-
Boron	30	-	84	<20	100	-	6	9	-	-	-	-	-
Cadmium	<0.2[DL>C]	-	<0.2[DL>C]	<0.005	<0.2[DL>C]	-	6	6	-	-	-	-	-
Chromium	<0.8	-	**1.5[C]**	<0.1	**1.5[C]**	-	7	9	-	22	-	-	-
Cobalt	<0.2	-	0.30	0.066	0.30	-	5	9	-	-	-	-	-
Copper	<1.0	-	1.0	0.40	1.0	-	6	9	-	-	-	-	-
Iron	**410[S]**	**517[S]**	**1,000[S]**	150	**1,000[S]**	377	0	9	-	-	-	-	56
Lead	<0.1	-	0.22	0.070	0.30	-	5	9	-	-	-	-	-
Lithium	<6.0	-	26	2.0	31	-	4	9	-	-	-	-	-
Manganese	38	44	**95[S]**	11	**109[S]**	30	0	9	-	-	-	-	22
Mercury	<0.0006	-	0.0017	<0.0006	0.0021	-	5	9	-	-	-	-	-
Methyl mercury	0.000060	-	0.00026	<0.00003	0.00031	-	3	9	-	-	-	-	-
Molybdenum	<0.1	-	0.20	0.090	0.20	-	4	9	-	-	-	-	-
Nickel	0.20	-	0.88	<0.2	1.0	-	4	9	-	-	-	-	-
Selenium	<0.4	-	**4.5[C]**	<0.04	**5.1[C]**	-	6	9	-	22	-	-	-
Silver	0.012	0.029	0.094	0.0020	0.10	0.037	2	9	-	-	-	-	-
Strontium	60	121	286	30	350	104	0	9	-	-	-	-	-
Thallium	<0.1	-	<0.1	0.0030	<0.1	-	7	9	-	-	-	-	-
Titanium	<5.0	-	<5.0	<0.5	<5.0	-	8	9	-	-	-	-	-
Uranium	<0.1	-	0.20	0.020	0.20	-	6	9	-	-	-	-	-
Vanadium	<0.2	-	0.80	<0.2	<1.0	-	6	9	-	-	-	-	-
Zinc	<4.0	-	9.0	3.0	9.0	-	4	9	-	-	-	-	-
Dissolved Metals													
Aluminum	<10	-	16	4.0	20	-	4	9	-	-	-	-	-
Antimony	0.50	-	0.86	<0.02	0.90	-	3	9	-	-	-	-	-
Arsenic	<0.4	-	0.40	0.18	0.40	-	6	9	-	-	-	-	-
Barium	30	30	48	20	60	12	0	9	-	-	-	-	-
Beryllium	<0.5	-	<0.5	<0.01	<0.5	-	9	9	-	-	-	-	-
Boron	32	33	87	9.0	110	32	2	9	-	-	-	-	-
Cadmium	<0.1	-	<0.1	<0.005	<0.1	-	9	9	-	-	-	-	-
Chromium	<0.4	-	4.8	<0.1	5.2	-	5	9	-	-	-	-	-
Cobalt	0.40	0.38	0.80	0.040	0.80	0.29	0	9	-	-	-	-	-
Copper	0.70	0.80	1.8	0.32	2.1	0.61	2	9	-	-	-	-	-
Iron	200	244	**400[C]**	100	**400[C]**	113	0	9	-	22	-	-	-
Lead	<0.1	-	0.46	0.050	0.50	-	5	9	-	-	-	-	-
Lithium	5.0	11	26	3.0	29	9.8	0	9	-	-	-	-	-
Manganese	17	25	54	9.0	64	19	0	9	-	-	-	-	-
Mercury	<0.0006	-	0.0014	<0.0006	0.0014	-	8	9	-	-	-	-	-
Molybdenum	0.10	0.14	0.30	<0.1	0.30	0.093	1	9	-	-	-	-	-
Nickel	0.50	0.85	2.1	<0.1	2.1	0.79	1	9	-	-	-	-	-
Selenium	<0.4	-	0.52	<0.04	0.60	-	7	9	-	-	-	-	-
Silver	<0.2	-	<0.2	<0.005	<0.2	-	6	6	-	-	-	-	-
Strontium	60	116	258	30	310	96	0	9	-	-	-	-	-
Thallium	<0.05	-	<0.05	<0.002	<0.05	-	9	9	-	-	-	-	-
Titanium	0.50	-	0.70	<0.3	0.70	-	3	9	-	-	-	-	-
Uranium	<0.1	-	0.10	0.020	0.10	-	6	9	-	-	-	-	-
Vanadium	0.30	-	0.30	0.10	<1.0	-	3	9	-	-	-	-	-
Zinc	7.0	36	140	2.0	140	59	0	9	-	-	-	-	-

Seasonal Summary – Summer

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.6	7.8	8.4	7.3	8.4	0.47	0	8	-	-	-	-	-
Specific conductivity	327	329	444	183	480	83	0	8	-	-	-	-	-
Temperature	**16[S]**	**16[S]**	**20[S]**	14	**21[S]**	2.2	0	8	-	-	-	-	75
Dissolved oxygen	9.0	9.2	14	**2.3[A, C]**	15	4.0	0	7	14	14	-	-	-
Conventional Parameters													
pH	8.2	8.2	8.3	8.0	8.3	0.12	0	10	-	-	-	-	-
Specific conductivity	312	329	578	184	618	142	0	10	-	-	-	-	-
Hardness, as $CaCO_3$	188	194	361	101	394	95	0	10	-	-	-	-	-
Total alkalinity, as $CaCO_3$	174	187	346	101	382	90	0	10	-	-	-	-	-
Total dissolved solids	216	232	419	120	450	106	0	10	-	-	-	-	-
Total suspended solids	3.0	-	18	<3.0	27	-	5	10	-	-	-	-	-
Total organic carbon	22	22	36	9.3	41	9.1	0	10	-	-	-	-	-
Dissolved organic carbon	22	22	35	8.7	39	8.7	0	10	-	-	-	-	-
Colour	**70[S]**	**78[S]**	**127[S]**	**28[S]**	**140[S]**	33	0	10	-	-	-	-	100
Major Ions													
Bicarbonate	213	227	422	124	467	111	0	10	-	-	-	-	-
Calcium	48	51	97	27	106	26	0	10	-	-	-	-	-
Carbonate	<5.0	-	<5.0	0.60	<5.0	-	9	10	-	-	-	-	-
Chloride	2.0	1.6	2.0	<1.0	2.0	0.60	1	10	-	-	-	-	-
Magnesium	17	16	29	7.9	32	7.8	0	10	-	-	-	-	-
Potassium	0.65	-	1.7	<0.5	2.4	-	3	10	-	-	-	-	-
Sodium	3.5	3.2	5.1	1.0	6.0	1.5	0	10	-	-	-	-	-
Sulphate	2.0	2.0	3.0	<1.0	3.0	0.90	1	10	-	-	-	-	-
Sulphide	0.0070	0.0072	0.013	<0.002	**0.014[C]**	0.0040	1	10	-	30	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.1	-	<0.1	<0.003	<0.1	-	10	10	-	-	-	-	-
Total ammonia	<0.05	-	0.080	<0.05	0.080	-	9	10	-	-	-	-	-
Total Kjeldahl nitrogen	0.80	0.87	1.4	0.60	1.7	0.32	0	10	-	-	-	-	-
Total nitrogen (calculated)	0.80	0.87	1.4	0.60	1.7	0.32	0	10	-	-	-	-	-
Total phosphorus	0.040	0.050	0.097	0.020	0.11	0.030	0	10	-	-	-	-	-
Dissolved phosphorus	0.020	0.027	0.059	0.013	0.059	0.018	0	10	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	4.6	<2.0	5.1	-	6	10	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	10	10	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0070[C, W]**	**0.0099[C, W]**	**0.022[C, W]**	<0.002	**0.028[C, W]**	0.0076	1	10	-	80	90	-	-
Total recoverable hydrocarbons	<1.0	-	<2.0	<1.0	<2.0	-	7	7	-	-	-	-	-
Total Metals													
Aluminum	30	45	122	<20	180	49	1	10	-	-	-	-	-
Antimony	0.50	0.48	0.88	<0.02	1.1	0.28	2	10	-	-	-	-	-
Arsenic	0.46	-	0.83	<0.4	1.1	-	5	10	-	-	-	-	-
Barium	40	44	79	23	93	21	0	10	-	-	-	-	-
Beryllium	<1.0	-	<1.0	<0.01	<1.0	-	10	10	-	-	-	-	-
Boron	20	-	60	<20	60	-	5	10	-	-	-	-	-
Cadmium	<0.2	-	<0.2[DL>C]	<0.005	<0.2[DL>C]	-	5	5	-	-	-	-	-
Chromium	<0.8	-	<0.8	<0.1	<0.8	-	10	10	-	-	-	-	-
Cobalt	<0.2	-	0.42	0.13	0.60	-	6	10	-	-	-	-	-
Copper	<1.0	-	<1.0	0.20	<1.0	-	9	10	-	-	-	-	-
Iron	**1,000[S]**	**735[S]**	**1,000[S]**	90	**1,000[S]**	356	0	10	-	-	-	-	90
Lead	<0.1	-	0.21	0.040	0.30	-	6	10	-	-	-	-	-
Lithium	<6.0	-	26	5.0	28	-	5	10	-	-	-	-	-
Manganese	**106[S]**	**187[S]**	**638[S]**	5.0	**1,000[S]**	293	0	10	-	-	-	-	60
Mercury	0.0010	-	0.0021	<0.0006	0.0022	-	4	10	-	-	-	-	-
Methyl mercury	0.000040	-	0.00032	<0.00003	0.00032	-	4	10	-	-	-	-	-
Molybdenum	0.10	-	0.29	<0.1	0.30	-	5	10	-	-	-	-	-
Nickel	1.0	1.1	2.5	<0.2	2.5	0.90	2	10	-	-	-	-	-
Selenium	<0.4	-	0.40	<0.04	0.40	-	9	10	-	-	-	-	-
Silver	0.035	0.034	0.071	0.0044	0.085	0.026	1	10	-	-	-	-	-
Strontium	65	155	340	50	380	127	0	10	-	-	-	-	-
Thallium	<0.1	-	<0.1	<0.002	<0.1	-	10	10	-	-	-	-	-
Titanium	<5.0	-	<5.0	<0.5	<5.0	-	10	10	-	-	-	-	-
Uranium	<0.1	-	<0.1	0.060	<0.1	-	9	10	-	-	-	-	-
Vanadium	0.30	0.40	1.0	0.10	1.3	0.38	2	10	-	-	-	-	-
Zinc	<4.0	-	6.1	1.0	7.0	-	7	10	-	-	-	-	-
Dissolved Metals													
Aluminum	<10	-	22	<10	23	-	8	10	-	-	-	-	-
Antimony	0.55	0.49	0.76	<0.02	0.80	0.24	2	10	-	-	-	-	-
Arsenic	0.50	-	0.88	<0.4	1.1	-	5	10	-	-	-	-	-
Barium	35	40	71	20	80	20	0	10	-	-	-	-	-
Beryllium	<0.5	-	<0.5	<0.01	<0.5	-	10	10	-	-	-	-	-
Boron	23	31	59	13	59	20	1	10	-	-	-	-	-
Cadmium	<0.1	-	<0.1	<0.005	<0.1	-	10	10	-	-	-	-	-
Chromium	<0.4	-	1.1	0.10	1.1	-	6	10	-	-	-	-	-
Cobalt	0.40	0.67	2.3	0.078	3.3	0.96	1	10	-	-	-	-	-
Copper	<0.6	-	1.2	0.11	1.2	-	8	10	-	-	-	-	-
Iron	300	**530[C]**	**1,000[C]**	100	**1,000[C]**	411	0	10	-	50	-	-	-
Lead	<0.1	-	<0.1	0.010	<0.1	-	9	10	-	-	-	-	-
Lithium	4.5	10	22	<3.0	23	8.7	1	10	-	-	-	-	-
Manganese	43	102	351	8.0	490	147	0	10	-	-	-	-	-
Mercury	<0.0006	-	<0.0006	<0.0006	<0.0006	-	10	10	-	-	-	-	-
Molybdenum	0.10	-	0.26	<0.1	0.30	-	3	10	-	-	-	-	-
Nickel	0.45	-	1.7	<0.1	2.0	-	4	10	-	-	-	-	-
Selenium	<0.4	-	0.40	<0.04	0.40	-	9	10	-	-	-	-	-
Silver	0.0054	-	<0.2	0.00080	<0.2	-	3	6	-	-	-	-	-
Strontium	65	146	303	50	330	113	0	10	-	-	-	-	-
Thallium	<0.05	-	<0.05	<0.002	<0.05	-	10	10	-	-	-	-	-
Titanium	0.61	-	1.8	<0.3	1.8	-	5	10	-	-	-	-	-
Uranium	<0.1	-	<0.1	0.050	<0.1	-	9	10	-	-	-	-	-
Vanadium	0.20	-	0.86	<0.1	0.90	-	4	10	-	-	-	-	-
Zinc	<2.0	-	3.0	0.40	3.0	-	7	10	-	-	-	-	-

Table V-1: Baseline Phase Seasonal Water Quality Data from the Firebag River Watershed Compared to Guidelines, 2006 to 2010

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
										A	C	W	D	S
Field Measured														
pH	-	8.0	8.0	8.2	7.8	8.2	0.20	0	3	-	-	-	-	-
Specific conductivity	µS/cm	215	282	463	142	490	184	0	3	-	-	-	-	-
Temperature	°C	4.9	3.8	5.6	0.80	5.7	2.6	0	3	-	-	-	-	-
Dissolved oxygen	mg/L	14	13	14	12	14	1.4	0	3	-	-	-	-	-
Conventional Parameters														
pH	-	8.2	8.2	8.2	8.1	8.2	0.055	0	5	-	-	-	-	-
Specific conductivity	µS/cm	316	338	587	180	643	188	0	5	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	173	192	353	92	389	121	0	5	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	170	181	322	89	354	107	0	5	-	-	-	-	-
Total dissolved solids	mg/L	213	233	387	137	420	116	0	5	-	-	-	-	-
Total suspended solids	mg/L	3.0	-	6.2	<1.0	7.0	-	2	5	-	-	-	-	-
Total organic carbon	mg/L	15	15	19	11	20	3.5	0	5	-	-	-	-	-
Dissolved organic carbon	mg/L	13	14	19	10	20	3.8	0	5	-	-	-	-	-
Colour	TCU	**35(S)**	**37(S)**	**48(S)**	**30(S)**	**50(S)**	8.3	0	5	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	207	221	393	110	432	130	0	5	-	-	-	-	-
Calcium	mg/L	44	48	85	24	94	28	0	5	-	-	-	-	-
Carbonate	mg/L	<5.0	-	<5.0	<0.5	<5.0	-	5	5	-	-	-	-	-
Chloride	mg/L	2.0	1.6	2.0	1.0	2.0	0.55	0	5	-	-	-	-	-
Magnesium	mg/L	15	18	34	7.6	38	12	0	5	-	-	-	-	-
Potassium	mg/L	0.70	1.0	2.0	<0.5	2.1	0.76	1	5	-	-	-	-	-
Sodium	mg/L	3.0	3.2	4.0	2.0	4.0	0.84	0	5	-	-	-	-	-
Sulphate	mg/L	2.0	3.3	9.2	<1.0	11	4.4	1	5	-	-	-	-	-
Sulphide	mg/L	0.0050	0.0041	0.0050	<0.003	0.0050	0.0015	1	5	-	-	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.1	-	<0.1	<0.003	<0.1	-	5	5	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	<0.05	<0.05	<0.05	-	5	5	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.50	0.58	0.84	0.40	0.90	0.19	0	5	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.50	0.58	0.84	0.40	0.90	0.19	0	5	-	-	-	-	-
Total phosphorus	mg-P/L	0.030	0.042	0.066	0.030	0.070	0.018	0	5	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.025	0.028	0.042	0.018	0.045	0.010	0	5	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	3.0	<2.0	3.0	-	4	5	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	<1.0	-	1.0	<1.0	1.0	-	4	5	-	-	-	-	-
Phenol(f)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics(g)	mg/L	<0.001	-	<0.002	<0.001	<0.002	-	5	5	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	<1.0	-	<2.0	<1.0	<2.0	-	5	5	-	-	-	-	-
Total Metals														
Aluminum	µg/L	<20	-	30	10	30	-	2	5	-	-	-	-	-
Antimony	µg/L	<0.4	-	<0.4	<0.02	<0.4	-	5	5	-	-	-	-	-
Arsenic	µg/L	<0.4	-	0.48	0.22	0.50	-	2	5	-	-	-	-	-
Barium	µg/L	37	46	81	21	87	27	0	5	-	-	-	-	-
Beryllium	µg/L	<1.0	-	<1.0	<0.01	<1.0	-	5	5	-	-	-	-	-
Boron	µg/L	<20	-	66	<20	70	-	3	5	-	-	-	-	-
Cadmium	µg/L	<0.2	-	<0.2(DL>C)	<0.005	<0.2(DL>C)	-	5	5	-	-	-	-	-
Chromium	µg/L	<0.8	-	<0.8	<0.1	<0.8	-	5	5	-	-	-	-	-
Cobalt	µg/L	0.20	0.19	0.30	0.041	0.30	0.12	1	5	-	-	-	-	-
Copper	µg/L	<1.0	-	<1.0	<0.05	<1.0	-	5	5	-	-	-	-	-
Iron	µg/L	**1,000(S)**	**842(S)**	**1,000(S)**	210	**1,000(S)**	353	0	5	-	-	-	-	80
Lead	µg/L	<0.1	-	<0.1	0.010	<0.1	-	4	5	-	-	-	-	-
Lithium	µg/L	<6.0	-	25	4.0	25	-	2	5	-	-	-	-	-
Manganese	µg/L	25	**60(S)**	**125(S)**	10	**128(S)**	55	0	5	-	-	-	-	40
Mercury	µg/L	<0.0006	-	0.0016	<0.0006	<0.002	-	4	5	-	-	-	-	-
Methyl mercury	µg/L	0.000060	0.000068	0.000096	0.000050	0.00010	0.000024	0	4	-	-	-	-	-
Molybdenum	µg/L	0.13	0.15	0.20	0.10	0.20	0.051	0	5	-	-	-	-	-
Nickel	µg/L	1.0	1.0	1.6	0.20	1.6	0.58	0	5	-	-	-	-	-
Selenium	µg/L	<0.4	-	<0.4	<0.04	<0.4	-	5	5	-	-	-	-	-
Silver	µg/L	<0.005	0.0037	0.0062	0.0010	0.0062	0.0023	1	5	-	-	-	-	-
Strontium	µg/L	80	152	306	50	320	124	0	5	-	-	-	-	-
Thallium	µg/L	<0.1	-	<0.1	<0.002	<0.1	-	5	5	-	-	-	-	-
Titanium	µg/L	<5.0	-	<5.0	<0.5	<5.0	-	5	5	-	-	-	-	-
Uranium	µg/L	<0.1	-	0.20	0.030	0.20	-	3	5	-	-	-	-	-
Vanadium	µg/L	0.30	-	0.46	<0.2	0.50	-	2	5	-	-	-	-	-
Zinc	µg/L	8.0	8.4	14	1.0	14	5.3	0	5	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	<10	-	<10	6.0	<10	-	4	5	-	-	-	-	-
Antimony	µg/L	0.60	0.50	0.68	<0.02	0.70	0.28	1	5	-	-	-	-	-
Arsenic	µg/L	<0.4	-	<0.4	0.22	<0.4	-	4	5	-	-	-	-	-
Barium	µg/L	30	40	74	20	80	25	0	5	-	-	-	-	-
Beryllium	µg/L	<0.5	-	<0.5	<0.01	<0.5	-	5	5	-	-	-	-	-
Boron	µg/L	<20	26	54	14	58	20	1	5	-	-	-	-	-
Cadmium	µg/L	<0.1	-	<0.1	<0.005	<0.1	-	5	5	-	-	-	-	-
Chromium	µg/L	1.2	0.97	1.4	<0.1	1.4	0.55	1	5	-	-	-	-	-
Cobalt	µg/L	0.30	0.27	0.40	0.029	0.40	0.16	0	5	-	-	-	-	-
Copper	µg/L	<0.6	-	<0.6	0.090	<0.6	-	4	5	-	-	-	-	-
Iron	µg/L	**400(C)**	**340(C)**	**400(C)**	100	**400(C)**	134	0	5	-	80	-	-	-
Lead	µg/L	<0.1	-	<0.1	0.010	<0.1	-	4	5	-	-	-	-	-
Lithium	µg/L	4.0	11	22	3.0	23	9.6	0	5	-	-	-	-	-
Manganese	µg/L	33	49	106	1.0	110	49	0	5	-	-	-	-	-
Mercury	µg/L	<0.0006	-	0.0020	<0.0006	0.0020	-	4	5	-	-	-	-	-
Molybdenum	µg/L	0.10	0.11	0.18	<0.1	0.20	0.055	1	5	-	-	-	-	-
Nickel	µg/L	0.70	0.72	1.3	0.20	1.4	0.44	0	5	-	-	-	-	-
Selenium	µg/L	<0.4	-	0.40	<0.04	0.40	-	4	5	-	-	-	-	-
Silver	µg/L	0.00090	-	0.0010	<0.0005	<0.005	-	2	5	-	-	-	-	-
Strontium	µg/L	60	128	252	50	260	103	0	5	-	-	-	-	-
Thallium	µg/L	<0.05	-	<0.05	<0.002	<0.05	-	5	5	-	-	-	-	-
Titanium	µg/L	<0.3	-	0.80	<0.3	0.80	-	4	5	-	-	-	-	-
Uranium	µg/L	<0.1	-	0.20	0.030	0.20	-	3	5	-	-	-	-	-
Vanadium	µg/L	0.50	0.46	0.60	<0.2	0.60	0.21	1	5	-	-	-	-	-
Zinc	µg/L	<2.0	-	3.6	1.0	4.0	-	2	5	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (63 to 509 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (6.6 to 8.4). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.20 mg-N/L) is is presented and was calculated based on the combination of field pH (8.4) and water temperature (17.8°C). The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline or below the recommended DO guideline.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.

- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO = dissolved oxygen.

Table V-2: Operational Phase Seasonal Water Quality Data from the Firebag River Watershed Compared to Guidelines, 2011 to 2018

Guidelines and Seasonal Summary – Winter

Parameter	Unit	GOA (2018) Aquatic Life Acute	GOA (2018) Aquatic Life Chronic	GOA (2018) Wildlife Health (Livestock)	Health Canada (2017) Drinking Water MAC	Health Canada (2017) Drinking Water AO	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above A	% Above C	% Above W	% Above D	% Above S
Field Measured																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	**6.6**[S]	**6.6**[S]	7.1	**5.6**[C, S]	7.1	0.54	0	6	-	17	-	-	67
Specific conductivity	μS/cm	-	-	-	-	-	220	247	354	206	396	73	0	6	-	-	-	-	-
Temperature	°C	-	-	-	-	15	0.030	-0.023	0.10	-0.32	0.10	0.16	0	6	-	-	-	-	-
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	**4.0**[A, C]	**5.6**[C]	12	**2.1**[A, C]	14	4.5	0	6	67	83	-	-	-
Conventional Parameters																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.7	7.7	8.0	7.4	8.1	0.23	0	6	-	-	-	-	-
Specific conductivity	μS/cm	-	-	-	-	-	220	222	230	210	230	7.5	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	109	110	119	104	120	6.2	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-	105	105	110	100	110	5.5	0	6	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	140	133	148	100	150	18	0	6	-	-	-	-	-
Total suspended solids	mg/L	-	-	-	-	-	<1.0	-	1.9	<1.0	2.1	-	4	6	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	5.1	5.7	8.1	4.3	8.7	1.7	0	6	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	5.0	5.5	8.0	4.1	8.8	1.7	0	6	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**20**[S]	**24**[S]	**38**[S]	14	**38**[S]	11	0	6	-	-	-	-	83
Major Ions																			
Bicarbonate	mg/L	-	-	-	-	-	130	132	140	120	140	7.5	0	6	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	29	29	30	27	30	0.97	0	6	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<0.5	-	<1.0	<0.5	<1.0	-	6	6	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	1.4	1.8	3.6	<1.0	4.1	1.3	1	6	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	8.8	8.9	9.6	8.3	9.8	0.49	0	6	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	1.0	1.0	1.1	0.85	1.1	0.099	0	6	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	3.8	3.8	4.1	3.4	4.1	0.27	0	6	-	-	-	-	-
Sulphate	mg/L	-	218 to 429[b, c]	1,000	-	500	1.8	1.8	2.9	<1.0	3.0	0.93	1	6	-	-	-	-	-
Sulphide	mg/L	-	0.0019 to 0.13[d]	-	-	0.050	<0.002	-	**0.010**[C]	<0.0019	**0.012**[C]	-	4	6	-	33	-	-	-
Nutrients and Biological Indicators																			
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.24	0.25	0.31	0.16	0.31	0.055	0	6	-	-	-	-	-
Total ammonia	mg-N/L	-	0.050[e]	-	-	-	0.095	0.090	0.15	<0.05	0.16	0.048	1	6	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	0.32	0.35	0.48	0.30	0.51	0.082	0	6	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	0.58	0.60	0.69	0.53	0.69	0.068	0	6	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.060	0.059	0.077	0.031	0.078	0.017	0	6	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.029	0.033	0.049	0.016	0.050	0.013	0	6	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	<2.0	-	<2.0	<2.0	<2.0	-	6	6	-	-	-	-	-
General Organics																			
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	6	6	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-	<0.002	-	0.0020	<0.002	0.0020	-	4	5	-	-	-	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	<2.0	<2.0	<2.0	-	6	6	-	-	-	-	-
Total Metals																			
Aluminum	μg/L	-	-	5,000	-	-	12	12	20	4.0	22	6.9	0	6	-	-	-	-	-
Antimony	μg/L	-	-	-	6.0	-	<0.02	-	<0.02	<0.02	<0.02	-	6	6	-	-	-	-	-
Arsenic	μg/L	-	5.0	25	10	-	0.26	0.26	0.29	0.22	0.29	0.026	0	6	-	-	-	-	-
Barium	μg/L	-	-	-	1,000	-	26	26	27	25	27	0.95	0	6	-	-	-	-	-
Beryllium	μg/L	-	-	100	-	-	<0.01	-	<0.01	<0.01	<0.01	-	6	6	-	-	-	-	-
Boron	μg/L	29,000	1,500	5,000	5,000	-	14	-	<50	12	<50	-	2	6	-	-	-	-	-
Cadmium	μg/L	0.86 to 7.1[b]	0.077 to 0.37[b]	80	5.0	-	<0.005	-	0.018	<0.005	0.018	-	5	6	-	-	-	-	-
Chromium	μg/L	-	1.0[h]	50	50[h]	-	<0.1	-	0.11	<0.1	0.11	-	4	6	-	-	-	-	-
Cobalt	μg/L	-	0.78 to 1.7[b]	1,000	-	-	0.035	0.036	0.045	0.026	0.046	0.0071	0	6	-	-	-	-	-
Copper	μg/L	6.8 to 52[b]	7.0[b]	500	-	1,000	0.21	0.17	0.29	<0.05	0.30	0.11	1	6	-	-	-	-	-
Iron	μg/L	-	-	-	-	300	**578**[S]	**587**[S]	**753**[S]	**420**[S]	**760**[S]	141	0	6	-	-	-	-	100
Lead	μg/L	-	1.0 to 7.0[b]	100	10	-	0.014	0.018	0.033	0.0070	0.035	0.011	0	6	-	-	-	-	-
Lithium	μg/L	-	-	-	-	-	4.0	4.1	4.6	3.9	4.7	0.30	0	6	-	-	-	-	-
Manganese	μg/L	-	-	-	-	50	30	28	41	11	43	11	0	6	-	-	-	-	-
Mercury	μg/L	0.013	0.0050	3.0	1.0	-	0.00052	0.00046	0.00062	0.00033	0.00062	0.00012	1	6	-	-	-	-	-
Methyl mercury	μg/L	0.0020	0.0010	-	-	-	<0.00008	-	<0.00008	<0.00008	<0.00008	-	6	6	-	-	-	-	-
Molybdenum	μg/L	-	73	500	-	-	0.22	0.22	0.26	0.19	0.27	0.026	0	6	-	-	-	-	-
Nickel	μg/L	223 to 1,298[b]	25 to 144[b]	1,000	-	-	0.14	0.15	0.22	0.094	0.22	0.061	0	6	-	-	-	-	-
Selenium	μg/L	-	2.0	50	50	-	<0.04	-	<0.04	<0.04	<0.04	-	6	6	-	-	-	-	-
Silver	μg/L	-	0.25	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	6	6	-	-	-	-	-
Strontium	μg/L	-	-	-	-	-	56	56	60	54	60	2.7	0	6	-	-	-	-	-
Thallium	μg/L	-	0.80	-	-	-	<0.002	-	<0.002	<0.002	<0.002	-	6	6	-	-	-	-	-
Titanium	μg/L	-	-	-	-	-	<0.5	-	0.61	<0.5	0.63	-	4	6	-	-	-	-	-
Uranium	μg/L	33	15	200	20	-	0.048	0.047	0.056	0.039	0.059	0.0071	0	6	-	-	-	-	-
Vanadium	μg/L	-	-	100	-	-	<0.2	-	0.27	<0.2	0.27	-	4	6	-	-	-	-	-
Zinc	μg/L	-	30	50,000	-	5,000	1.6	1.8	3.5	0.64	3.8	1.3	0	6	-	-	-	-	-
Dissolved Metals																			
Aluminum	μg/L	34 to 100[d]	12 to 50[d]	-	-	-	2.3	3.0	5.6	1.9	6.5	1.8	0	6	-	-	-	-	-
Antimony	μg/L	-	-	-	-	-	<0.02	-	<0.02	<0.02	<0.02	-	6	6	-	-	-	-	-
Arsenic	μg/L	-	-	-	-	-	0.18	0.19	0.24	0.13	0.25	0.043	0	6	-	-	-	-	-
Barium	μg/L	-	-	-	-	-	27	27	30	23	30	2.3	0	6	-	-	-	-	-
Beryllium	μg/L	-	-	-	-	-	<0.01	-	<0.01	<0.01	<0.01	-	6	6	-	-	-	-	-
Boron	μg/L	-	-	-	-	-	15	-	<50	12	<50	-	2	6	-	-	-	-	-
Cadmium	μg/L	-	-	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	6	6	-	-	-	-	-
Chromium	μg/L	-	-	-	-	-	<0.1	-	0.11	<0.1	0.11	-	5	6	-	-	-	-	-
Cobalt	μg/L	-	-	-	-	-	0.026	0.026	0.031	0.021	0.031	0.0037	0	6	-	-	-	-	-
Copper	μg/L	-	-	-	-	-	0.068	0.45	1.8	<0.05	2.4	0.95	1	6	-	-	-	-	-
Iron	μg/L	-	300	-	-	-	260	267	**389**[C]	100	**398**[C]	105	0	6	-	33	-	-	-
Lead	μg/L	-	-	-	-	-	0.0051	-	0.019	<0.005	0.020	-	3	6	-	-	-	-	-
Lithium	μg/L	-	-	-	-	-	3.9	4.0	4.5	3.5	4.6	0.38	0	6	-	-	-	-	-
Manganese	μg/L	-	-	-	-	-	16	17	29	1.6	32	9.7	0	6	-	-	-	-	-
Mercury	μg/L	-	-	-	-	-	0.00026	-	0.00038	<0.00011	<0.0006	-	2	6	-	-	-	-	-
Molybdenum	μg/L	-	-	-	-	-	0.22	0.22	0.28	0.18	0.30	0.042	0	6	-	-	-	-	-
Nickel	μg/L	-	-	-	-	-	0.10	0.13	0.26	0.088	0.30	0.084	0	6	-	-	-	-	-
Selenium	μg/L	-	-	-	-	-	<0.04	-	<0.04	<0.04	<0.04	-	6	6	-	-	-	-	-
Silver	μg/L	-	-	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	6	6	-	-	-	-	-
Strontium	μg/L	-	-	-	-	-	56	56	59	52	60	2.7	0	6	-	-	-	-	-
Thallium	μg/L	-	-	-	-	-	<0.002	-	<0.002	<0.002	<0.002	-	6	6	-	-	-	-	-
Titanium	μg/L	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	-	6	6	-	-	-	-	-
Uranium	μg/L	-	-	-	-	-	0.046	0.046	0.053	0.040	0.054	0.0053	0	6	-	-	-	-	-
Vanadium	μg/L	-	-	-	-	-	<0.2	-	<0.2	<0.2	<0.2	-	6	6	-	-	-	-	-
Zinc	μg/L	-	-	-	-	-	0.47	0.85	1.9	0.30	2.0	0.71	0	6	-	-	-	-	-

Seasonal Summary – Spring

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above A	% Above C	% Above W	% Above D	% Above S
Field Measured													
pH	7.5	7.6	8.7	**6.9**[S]	9.0	0.67	0	8	-	-	-	-	13
Specific conductivity	140	222	479	111	493	158	0	8	-	-	-	-	-
Temperature	4.6	5.7	14	0	**16**[S]	6.1	0	8	-	-	-	-	13
Dissolved oxygen	11	11	13	6.7	14	2.0	0	8	-	-	-	-	-
Conventional Parameters													
pH	8.0	8.0	8.2	7.7	8.2	0.14	0	8	-	-	-	-	-
Specific conductivity	160	199	402	88	500	130	0	8	-	-	-	-	-
Hardness, as $CaCO_3$	83	104	218	42	279	74	0	8	-	-	-	-	-
Total alkalinity, as $CaCO_3$	78	100	217	41	280	76	0	8	-	-	-	-	-
Total dissolved solids	100	126	241	68	300	73	0	8	-	-	-	-	-
Total suspended solids	6.5	9.6	27	<0.5	32	11	1	8	-	-	-	-	-
Total organic carbon	11	11	16	4.4	16	4.1	0	8	-	-	-	-	-
Dissolved organic carbon	11	10	15	4.4	15	3.9	0	8	-	-	-	-	-
Colour	**40**[S]	**44**[S]	**82**[S]	**16**[S]	**92**[S]	24	0	8	-	-	-	-	100
Major Ions													
Bicarbonate	97	122	263	50	340	92	0	8	-	-	-	-	-
Calcium	22	28	57	12	72	19	0	8	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	8	8	-	-	-	-	-
Chloride	1.2	-	2.0	<1.0	2.0	-	3	8	-	-	-	-	-
Magnesium	6.5	8.7	19	3.8	25	6.8	0	8	-	-	-	-	-
Potassium	1.1	1.1	1.6	0.59	1.7	0.32	0	8	-	-	-	-	-
Sodium	3.0	3.0	3.7	1.7	4.0	0.63	0	8	-	-	-	-	-
Sulphate	<1.0	-	2.7	<1.0	3.0	-	6	8	-	-	-	-	-
Sulphide	<0.002	-	**0.080**[S]	<0.0019	**0.12**[C, S]	-	6	8	-	25	-	-	13
Nutrients and Biological Indicators													
Nitrate + nitrite	0.011	-	0.25	<0.003	0.27	-	4	8	-	-	-	-	-
Total ammonia	<0.05	-	0.27	<0.015	0.36	-	6	8	-	-	-	-	-
Total Kjeldahl nitrogen	0.60	0.62	0.90	0.30	0.90	0.21	0	8	-	-	-	-	-
Total nitrogen (calculated)	0.65	0.71	1.0	0.48	1.1	0.22	0	8	-	-	-	-	-
Total phosphorus	0.070	0.067	0.089	0.020	0.090	0.022	0	8	-	-	-	-	-
Dissolved phosphorus	0.028	0.027	0.039	0.010	0.040	0.010	0	8	-	-	-	-	-
Biochemical oxygen demand	2.1	-	2.5	<2.0	2.5	-	4	8	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	8	8	-	-	-	-	-
Phenol[f]	**0.0051**[C, W]	-	**0.0051**[C, W]	-	-	-	0	1	-	100	100	-	-
Total phenolics[g]	**0.0026**[W]	-	**0.0051**[C, W]	<0.002	**0.0052**[C, W]	-	2	7	-	29	57	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	8	8	-	-	-	-	-
Total Metals													
Aluminum	30	56	164	10	220	69	0	8	-	-	-	-	-
Antimony	<0.02	-	<0.1	<0.02	<0.1	-	7	8	-	-	-	-	-
Arsenic	0.35	0.31	0.39	0.10	0.40	0.098	0	8	-	-	-	-	-
Barium	24	26	41	17	49	9.8	0	8	-	-	-	-	-
Beryllium	<0.01	-	0.010	<0.01	<0.05	-	7	8	-	-	-	-	-
Boron	<50	-	<300	18	<300	-	7	8	-	-	-	-	-
Cadmium	0.0090	-	0.021	<0.005	<0.03	-	3	8	-	-	-	-	-
Chromium	0.18	-	<0.5	<0.1	<0.5	-	3	8	-	-	-	-	-
Cobalt	0.084	0.090	0.16	0.043	0.19	0.045	0	8	-	-	-	-	-
Copper	0.26	0.31	0.50	0.17	0.50	0.14	0	8	-	-	-	-	-
Iron	**1,000**[S]	**925**[S]	**1,169**[S]	**431**[S]	**1,260**[S]	248	0	8	-	-	-	-	100
Lead	0.061	0.081	0.17	0.040	0.17	0.054	1	8	-	-	-	-	-
Lithium	3.3	4.2	8.6	1.8	11	2.9	0	8	-	-	-	-	-
Manganese	**70**[S]	**77**[S]	**134**[S]	27	**155**[S]	39	0	8	-	-	-	-	75
Mercury	0.00090	-	0.0037	<0.0006	0.0046	-	3	8	-	-	-	-	-
Methyl mercury	0.000090	-	0.00012	<0.00003	0.00012	-	4	8	-	-	-	-	-
Molybdenum	0.20	0.25	0.46	0.15	0.54	0.13	1	8	-	-	-	-	-
Nickel	0.30	0.29	0.44	0.10	0.49	0.11	0	8	-	-	-	-	-
Selenium	<0.04	-	0.20	<0.04	0.20	-	7	8	-	-	-	-	-
Silver	<0.005	-	<0.03	<0.005	<0.03	-	7	8	-	-	-	-	-
Strontium	45	52	93	25	110	26	0	8	-	-	-	-	-
Thallium	0.0020	-	0.0020	<0.002	<0.01	-	5	8	-	-	-	-	-
Titanium	1.9	-	5.8	<0.5	5.8	-	4	8	-	-	-	-	-
Uranium	0.045	0.048	0.077	0.030	0.090	0.019	0	8	-	-	-	-	-
Vanadium	0.33	-	0.56	<0.2	<1.0	-	3	8	-	-	-	-	-
Zinc	1.3	1.4	2.0	<1.0	2.0	0.58	1	8	-	-	-	-	-
Dissolved Metals													
Aluminum	7.0	10	29	1.6	40	12	0	8	-	-	-	-	-
Antimony	<0.02	-	0.021	<0.02	0.021	-	7	8	-	-	-	-	-
Arsenic	0.26	0.24	0.32	0.13	0.32	0.068	0	8	-	-	-	-	-
Barium	20	22	40	14	50	11	0	8	-	-	-	-	-
Beryllium	<0.01	-	<0.01	<0.01	<0.01	-	8	8	-	-	-	-	-
Boron	<50	-	<50	15	<50	-	6	8	-	-	-	-	-
Cadmium	<0.005	-	0.0093	<0.005	0.011	-	6	8	-	-	-	-	-
Chromium	<0.1	-	0.10	<0.1	0.10	-	7	8	-	-	-	-	-
Cobalt	0.044	0.048	0.075	0.030	0.079	0.017	0	8	-	-	-	-	-
Copper	0.15	0.84	3.0	0.082	3.2	1.3	0	8	-	-	-	-	-
Iron	**400**[C]	**388**[C]	**755**[C]	64	**946**[C]	257	0	8	-	63	-	-	-
Lead	0.020	0.029	0.074	<0.005	0.081	0.028	1	8	-	-	-	-	-
Lithium	3.5	4.0	7.3	1.9	9.0	2.2	0	8	-	-	-	-	-
Manganese	6.5	25	98	0.70	140	47	0	8	-	-	-	-	-
Mercury	<0.001	-	0.0028	0.00058	0.0030	-	4	8	-	-	-	-	-
Molybdenum	0.20	0.23	0.37	0.10	0.40	0.096	0	8	-	-	-	-	-
Nickel	0.23	0.28	0.50	0.10	0.55	0.14	0	8	-	-	-	-	-
Selenium	<0.04	-	<0.04	<0.04	<0.04	-	8	8	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	8	8	-	-	-	-	-
Strontium	44	50	86	27	100	23	0	8	-	-	-	-	-
Thallium	<0.002	-	<0.002	<0.002	<0.002	-	8	8	-	-	-	-	-
Titanium	<0.5	-	0.89	<0.5	0.89	-	7	8	-	-	-	-	-
Uranium	0.035	0.032	0.047	0.018	0.050	0.012	0	8	-	-	-	-	-
Vanadium	<0.2	-	0.30	<0.2	0.32	-	6	8	-	-	-	-	-
Zinc	1.0	0.94	2.3	<0.1	3.0	0.93	1	8	-	-	-	-	-

Seasonal Summary – Summer

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above A	% Above C	% Above W	% Above D	% Above S
Field Measured													
pH	9.0	8.6	**9.1**[C]	7.8	**9.1**[C]	0.72	0	3	-	33	-	-	-
Specific conductivity	189	249	414	166	451	136	0	4	-	-	-	-	-
Temperature	**19**[S]	**18**[S]	**20**[S]	15	**20**[S]	2.3	0	4	-	-	-	-	75
Dissolved oxygen	10	10	14	**6.2**[C]	15	3.6	0	4	-	25	-	-	-
Conventional Parameters													
pH	8.3	8.4	8.9	8.0	**9.0**[C]	0.46	0	4	-	25	-	-	-
Specific conductivity	200	288	523	170	580	196	0	4	-	-	-	-	-
Hardness, as $CaCO_3$	107	162	300	100	333	114	0	4	-	-	-	-	-
Total alkalinity, as $CaCO_3$	100	153	287	90	320	112	0	4	-	-	-	-	-
Total dissolved solids	145	198	346	120	380	122	0	4	-	-	-	-	-
Total suspended solids	3.0	-	3.0	<1.0	3.0	-	2	4	-	-	-	-	-
Total organic carbon	17	18	29	9.0	30	10.0	0	4	-	-	-	-	-
Dissolved organic carbon	17	17	27	8.0	28	9.4	0	4	-	-	-	-	-
Colour	**55**[S]	**60**[S]	**94**[S]	**31**[S]	**98**[S]	32	0	4	-	-	-	-	100
Major Ions													
Bicarbonate	115	183	358	100	400	145	0	4	-	-	-	-	-
Calcium	29	44	82	26	91	32	0	4	-	-	-	-	-
Carbonate	3.3	-	9.0	<0.5	10	-	2	4	-	-	-	-	-
Chloride	1.0	-	1.9	<1.0	2.0	-	1	4	-	-	-	-	-
Magnesium	8.2	13	24	7.3	27	9.6	0	4	-	-	-	-	-
Potassium	0.69	0.82	1.4	0.41	1.5	0.48	0	4	-	-	-	-	-
Sodium	3.2	3.4	3.9	3.0	4.0	0.47	0	4	-	-	-	-	-
Sulphate	<1.0	-	<1.0	<1.0	<1.0	-	4	4	-	-	-	-	-
Sulphide	<0.002	-	<0.002	<0.0019	<0.002	-	4	4	-	-	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	0.0095	-	0.012	0.0050	<0.014	-	1	4	-	-	-	-	-
Total ammonia	<0.05	-	<0.05	0.032	<0.05	-	3	4	-	-	-	-	-
Total Kjeldahl nitrogen	0.85	0.75	0.90	0.40	0.90	0.24	0	4	-	-	-	-	-
Total nitrogen (calculated)	0.86	0.76	0.91	0.40	0.91	0.24	0	4	-	-	-	-	-
Total phosphorus	0.045	0.058	0.11	0.021	0.12	0.045	0	4	-	-	-	-	-
Dissolved phosphorus	0.0097	0.025	0.067	0.0030	0.077	0.035	0	4	-	-	-	-	-
Biochemical oxygen demand	2.0	-	2.1	<2.0	2.1	-	2	4	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	4	4	-	-	-	-	-
Phenol[f]	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-
Total phenolics[g]	**0.0025**[W]	**0.0025**[W]	**0.0030**[W]	0.0020	**0.0030**[W]	0.00071	0	2	-	-	50	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	4	4	-	-	-	-	-
Total Metals													
Aluminum	20	23	47	2.7	50	21	0	4	-	-	-	-	-
Antimony	<0.02	-	0.040	<0.02	0.040	-	3	4	-	-	-	-	-
Arsenic	0.46	0.52	0.68	0.43	0.71	0.13	0	4	-	-	-	-	-
Barium	26	33	55	20	60	18	0	4	-	-	-	-	-
Beryllium	<0.01	-	<0.01	<0.01	<0.01	-	4	4	-	-	-	-	-
Boron	<50	-	53	13	53	-	2	4	-	-	-	-	-
Cadmium	0.0060	-	0.015	<0.005	0.016	-	2	4	-	-	-	-	-
Chromium	0.10	-	0.19	<0.1	0.20	-	1	4	-	-	-	-	-
Cobalt	0.088	0.085	0.11	0.054	0.11	0.028	0	4	-	-	-	-	-
Copper	0.10	-	0.27	<0.05	0.30	-	1	4	-	-	-	-	-
Iron	**345**[S]	**485**[S]	**906**[S]	250	**1,000**[S]	347	0	4	-	-	-	-	75
Lead	0.030	-	0.064	<0.005	0.070	-	1	4	-	-	-	-	-
Lithium	4.0	8.0	18	3.0	21	8.7	0	4	-	-	-	-	-
Manganese	**55**[S]	42	**55**[S]	16	**55**[S]	23	0	3	-	-	-	-	67
Mercury	<0.0006	-	0.00071	<0.0006	0.00071	-	3	4	-	-	-	-	-
Methyl mercury	0.00022	-	0.00036	<0.00003	0.00038	-	2	4	-	-	-	-	-
Molybdenum	0.17	0.16	0.19	0.10	0.19	0.040	0	4	-	-	-	-	-
Nickel	0.26	0.28	0.49	0.10	0.50	0.20	0	4	-	-	-	-	-
Selenium	0.040	-	0.046	<0.04	0.047	-	2	4	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	4	4	-	-	-	-	-
Strontium	60	107	222	57	250	96	0	4	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	3	4	-	-	-	-	-
Titanium	0.60	-	0.77	<0.5	0.80	-	2	4	-	-	-	-	-
Uranium	0.035	0.053	0.11	0.020	0.12	0.046	0	4	-	-	-	-	-
Vanadium	<0.2	-	0.36	<0.2	0.36	-	3	4	-	-	-	-	-
Zinc	1.0	1.1	1.9	0.43	2.0	0.65	0	4	-	-	-	-	-
Dissolved Metals													
Aluminum	5.0	5.5	9.6	1.9	10	3.7	0	4	-	-	-	-	-
Antimony	<0.02	-	0.030	<0.02	0.030	-	3	4	-	-	-	-	-
Arsenic	0.43	0.46	0.58	0.39	0.60	0.096	0	4	-	-	-	-	-
Barium	25	32	56	19	60	19	0	4	-	-	-	-	-
Beryllium	<0.01	-	0.010	<0.01	0.010	-	3	4	-	-	-	-	-
Boron	<50	-	63	13	63	-	2	4	-	-	-	-	-
Cadmium	0.0050	-	0.0050	<0.005	0.0050	-	2	4	-	-	-	-	-
Chromium	0.12	-	0.27	<0.1	0.30	-	2	4	-	-	-	-	-
Cobalt	0.070	0.070	0.092	0.047	0.093	0.025	0	4	-	-	-	-	-
Copper	0.10	0.16	0.34	0.050	0.38	0.15	0	4	-	-	-	-	-
Iron	125	**338**[C]	**873**[C]	100	**1,000**[C]	442	0	4	-	25	-	-	-
Lead	0.015	-	0.037	<0.005	0.040	-	1	4	-	-	-	-	-
Lithium	4.1	8.3	19	3.0	22	9.2	0	4	-	-	-	-	-
Manganese	7.5	7.6	12	3.2	12	4.1	0	4	-	-	-	-	-
Mercury	<0.0006	-	0.0020	0.00029	0.0020	-	2	4	-	-	-	-	-
Molybdenum	0.20	0.18	0.21	0.10	0.21	0.052	0	4	-	-	-	-	-
Nickel	0.35	0.61	1.4	0.13	1.6	0.68	0	4	-	-	-	-	-
Selenium	0.040	-	0.043	<0.04	0.043	-	2	4	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	4	4	-	-	-	-	-
Strontium	60	107	222	59	250	95	0	4	-	-	-	-	-
Thallium	<0.002	-	<0.002	<0.002	<0.002	-	4	4	-	-	-	-	-
Titanium	<0.5	-	<0.5	<0.5	<0.5	-	4	4	-	-	-	-	-
Uranium	0.042	0.051	0.092	0.020	0.10	0.034	0	4	-	-	-	-	-
Vanadium	<0.2	-	0.30	<0.2	0.30	-	3	4	-	-	-	-	-
Zinc	1.0	1.3	2.7	0.16	3.0	1.2	0	4	-	-	-	-	-

Table V-2: Operational Phase Seasonal Water Quality Data from the Firebag River Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	Seasonal Summary – Fall								% Above Guideline				
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	A	C	W	D	S
Field Measured														
pH	-	7.9	7.8	8.1	7.0	8.1	0.45	0	5	-	-	-	-	-
Specific conductivity	μS/cm	153	167	209	116	210	37	0	7	-	-	-	-	-
Temperature	°C	3.5	4.0	10	0.33	12	4.2	0	7	-	-	-	-	-
Dissolved oxygen	mg/L	14	15	24	11	29	6.0	0	7	-	-	-	-	-
Conventional Parameters														
pH	-	8.1	8.1	8.2	7.7	8.2	0.16	0	8	-	-	-	-	-
Specific conductivity	μS/cm	190	186	210	150	210	24	0	8	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	96	96	113	77	114	14	0	8	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	92	93	110	72	110	14	0	8	-	-	-	-	-
Total dissolved solids	mg/L	125	128	153	110	160	17	0	8	-	-	-	-	-
Total suspended solids	mg/L	1.7	-	5.8	<1.0	5.9	-	2	8	-	-	-	-	-
Total organic carbon	mg/L	9.5	10	15	7.4	15	2.8	0	8	-	-	-	-	-
Dissolved organic carbon	mg/L	10	11	16	8.1	18	3.3	0	8	-	-	-	-	-
Colour	TCU	**46**[(S)]	**44**[(S)]	**55**[(S)]	**26**[(S)]	**56**[(S)]	9.9	0	8	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	115	113	130	88	130	17	0	8	-	-	-	-	-
Calcium	mg/L	25	25	29	21	29	3.2	0	8	-	-	-	-	-
Carbonate	mg/L	<0.5	-	<1.0	<0.5	<1.0	-	8	8	-	-	-	-	-
Chloride	mg/L	1.0	-	1.3	<1.0	1.4	-	2	8	-	-	-	-	-
Magnesium	mg/L	7.7	7.7	8.9	6.6	9.2	0.93	0	8	-	-	-	-	-
Potassium	mg/L	0.63	0.65	0.87	0.45	0.89	0.15	0	8	-	-	-	-	-
Sodium	mg/L	3.3	3.3	3.8	3.0	4.0	0.33	0	8	-	-	-	-	-
Sulphate	mg/L	<1.0	-	<1.0	<1.0	<1.0	-	8	8	-	-	-	-	-
Sulphide	mg/L	<0.002	-	0.0023	<0.0019	0.0023	-	7	8	-	-	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.014	-	0.028	<0.01	0.031	-	5	8	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	<0.05	<0.015	<0.05	-	8	8	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.43	0.43	0.57	0.31	0.60	0.090	0	8	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.43	0.44	0.59	0.31	0.63	0.10	0	8	-	-	-	-	-
Total phosphorus	mg-P/L	0.050	0.051	0.068	0.030	0.073	0.013	0	8	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.026	0.028	0.047	0.018	0.055	0.012	0	8	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	2.6	<2.0	2.6	-	7	8	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	<1.0	-	<1.0	<1.0	<1.0	-	8	8	-	-	-	-	-
Phenol[(f)]	mg/L	<0.002	-	**0.0047**[(C, W)]	<0.002	**0.0047**[(C, W)]	-	2	3	-	33	33	-	-
Total phenolics[(a)]	mg/L	**0.0036**[(W)]	**0.0037**[(W)]	**0.0056**[(C, W)]	0.0020	**0.0060**[(C, W)]	0.0015	0	5	-	20	80	-	-
Total recoverable hydrocarbons	mg/L	<2.0	-	<2.0	<2.0	<2.0	-	7	7	-	-	-	-	-
Total Metals														
Aluminum	μg/L	12	14	25	5.7	27	6.9	0	8	-	-	-	-	-
Antimony	μg/L	<0.02	-	<0.02	<0.02	<0.02	-	8	8	-	-	-	-	-
Arsenic	μg/L	0.31	0.32	0.41	0.28	0.44	0.054	0	8	-	-	-	-	-
Barium	μg/L	22	21	23	16	23	2.3	0	8	-	-	-	-	-
Beryllium	μg/L	<0.01	-	0.010	<0.01	0.010	-	7	8	-	-	-	-	-
Boron	μg/L	<20	-	<50	11	<50	-	5	8	-	-	-	-	-
Cadmium	μg/L	<0.005	-	<0.005	<0.005	<0.005	-	8	8	-	-	-	-	-
Chromium	μg/L	<0.1	-	0.11	<0.1	0.11	-	7	8	-	-	-	-	-
Cobalt	μg/L	0.053	0.051	0.067	0.031	0.072	0.013	0	8	-	-	-	-	-
Copper	μg/L	0.10	-	0.20	0.092	0.25	-	2	8	-	-	-	-	-
Iron	μg/L	**587**[(S)]	**642**[(S)]	**1,000**[(S)]	**412**[(S)]	**1,000**[(S)]	239	0	8	-	-	-	-	100
Lead	μg/L	0.024	-	0.054	0.011	0.060	-	2	8	-	-	-	-	-
Lithium	μg/L	3.6	3.6	4.0	3.0	4.0	0.41	0	8	-	-	-	-	-
Manganese	μg/L	30	32	50	17	**51**[(S)]	14	0	8	-	-	-	-	13
Mercury	μg/L	0.00068	-	0.00092	0.00059	0.0010	-	2	8	-	-	-	-	-
Methyl mercury	μg/L	<0.00008	-	0.000090	0.000040	0.000090	-	6	8	-	-	-	-	-
Molybdenum	μg/L	0.17	0.16	0.22	0.094	0.24	0.047	0	8	-	-	-	-	-
Nickel	μg/L	0.20	0.20	0.30	0.10	0.30	0.069	0	8	-	-	-	-	-
Selenium	μg/L	<0.04	-	<0.04	<0.04	<0.04	-	8	8	-	-	-	-	-
Silver	μg/L	<0.005	-	<0.01	<0.005	<0.01	-	8	8	-	-	-	-	-
Strontium	μg/L	49	48	57	40	57	6.6	0	8	-	-	-	-	-
Thallium	μg/L	<0.002	-	<0.002	<0.002	<0.002	-	8	8	-	-	-	-	-
Titanium	μg/L	0.93	-	<2.0	<0.5	<2.0	-	6	8	-	-	-	-	-
Uranium	μg/L	0.034	0.033	0.048	0.020	0.052	0.011	0	8	-	-	-	-	-
Vanadium	μg/L	0.21	-	0.27	<0.2	0.28	-	3	8	-	-	-	-	-
Zinc	μg/L	<1.0	-	1.7	0.38	2.0	-	3	8	-	-	-	-	-
Dissolved Metals														
Aluminum	μg/L	3.2	4.5	8.3	2.6	9.0	2.4	0	8	-	-	-	-	-
Antimony	μg/L	<0.02	-	<0.02	<0.02	<0.02	-	8	8	-	-	-	-	-
Arsenic	μg/L	0.26	0.28	0.38	0.23	0.41	0.059	0	8	-	-	-	-	-
Barium	μg/L	20	20	21	19	21	0.75	0	8	-	-	-	-	-
Beryllium	μg/L	<0.01	-	<0.01	<0.01	<0.01	-	8	8	-	-	-	-	-
Boron	μg/L	<20	-	<50	11	<50	-	5	8	-	-	-	-	-
Cadmium	μg/L	<0.005	-	<0.005	<0.005	<0.005	-	8	8	-	-	-	-	-
Chromium	μg/L	<0.1	-	0.20	<0.1	0.20	-	7	8	-	-	-	-	-
Cobalt	μg/L	0.039	0.040	0.050	0.032	0.054	0.0064	0	8	-	-	-	-	-
Copper	μg/L	0.086	-	0.10	<0.05	0.10	-	3	8	-	-	-	-	-
Iron	μg/L	280	**303**[(C)]	**444**[(C)]	200	**500**[(C)]	89	0	8	-	25	-	-	-
Lead	μg/L	0.0095	0.014	0.038	<0.005	0.047	0.014	1	8	-	-	-	-	-
Lithium	μg/L	3.5	3.5	4.1	3.0	4.1	0.42	0	8	-	-	-	-	-
Manganese	μg/L	9.3	9.3	18	2.0	21	5.7	0	8	-	-	-	-	-
Mercury	μg/L	0.00045	0.00058	0.0010	0.00037	0.0011	0.00029	1	8	-	-	-	-	-
Molybdenum	μg/L	0.20	0.19	0.23	0.15	0.24	0.031	0	8	-	-	-	-	-
Nickel	μg/L	0.17	0.18	0.27	0.13	0.30	0.053	0	8	-	-	-	-	-
Selenium	μg/L	<0.04	-	0.042	<0.04	0.042	-	7	8	-	-	-	-	-
Silver	μg/L	<0.005	-	<0.005	<0.005	<0.005	-	8	8	-	-	-	-	-
Strontium	μg/L	48	48	56	40	56	6.0	0	8	-	-	-	-	-
Thallium	μg/L	<0.002	-	<0.002	<0.002	<0.002	-	8	8	-	-	-	-	-
Titanium	μg/L	<0.5	-	<0.5	<0.5	<0.5	-	8	8	-	-	-	-	-
Uranium	μg/L	0.033	0.033	0.045	0.020	0.048	0.0098	0	8	-	-	-	-	-
Vanadium	μg/L	<0.2	-	0.22	<0.2	0.23	-	6	8	-	-	-	-	-
Zinc	μg/L	0.44	0.74	1.8	0.10	2.0	0.68	0	8	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (42 to 333 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (5.6 to 9.1). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.050 mg-N/L) is presented and was calculated based on the combination of field pH (9.1) and water temperature (19.2°C). Guidelines calculated with temperature and pH values falling outside the defined range (i.e., pH 6.0 to 10.0 and temperature 0°C to 30°C) should be used with caution, as the WQG does not necessarily accurately reflect toxic effects at the low and high pH and temperature extremes. The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline, below the recommended DO guideline, or outside the recommended pH range.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.
- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO = dissolved oxygen.

Table V-3: Baseline Phase Seasonal Water Quality Data from the Muskeg Creek Watershed Compared to Guidelines, 2006 to 2010

Parameter	Unit	GOA (2018) Guidelines for the Protection of: Aquatic Life – Acute	Aquatic Life – Chronic	Wildlife Health (Livestock)	Health Canada (2017) Drinking Water MAC	Drinking Water AO	Winter Median	Winter Mean	Winter 95th Percentile	Winter Minimum	Winter Maximum	Winter Standard Deviation	Winter nd	Winter Count	% Above Guideline A	C	W	D	S
Field Measured																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.3	-	7.3	-	-	-	0	1	-	-	-	-	-
Specific conductivity	μS/cm	-	-	-	-	-	731	-	731	-	-	-	0	1	-	-	-	-	-
Temperature	°C	-	-	-	-	15	8.9	-	8.9	-	-	-	0	1	-	-	-	-	-
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	7.3	-	7.3	-	-	-	0	1	-	-	-	-	-
Conventional Parameters																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.8	7.8	7.8	7.7	7.8	0.071	0	2	-	-	-	-	-
Specific conductivity	μS/cm	-	-	-	-	-	613	613	916	275	950	477	0	2	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	231	231	320	131	330	141	0	2	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-	339	339	511	147	530	271	0	2	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	415	415	**582**[S]	230	**600**[S]	262	0	2	-	-	-	-	50
Total suspended solids	mg/L	-	-	-	-	-	172	172	323	3.0	340	238	0	2	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	38	38	41	34	41	4.9	0	2	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	39	39	42	36	42	4.2	0	2	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**114**[S]	**114**[S]	**146**[S]	**77**[S]	**150**[S]	52	0	2	-	-	-	-	100
Major Ions																			
Bicarbonate	mg/L	-	-	-	-	-	415	415	627	180	650	332	0	2	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	53	53	73	31	75	31	0	2	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<5.0	-	<5.0	<0.5	<5.0	-	2	2	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	3.0	3.0	3.9	2.0	4.0	1.4	0	2	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	23	23	34	11	35	17	0	2	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	3.4	3.4	4.8	1.8	5.0	2.3	0	2	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	80	80	139	14	146	93	0	2	-	-	-	-	-
Sulphate	mg/L	-	218 to 429[b, c]	1,000	-	500	5.0	5.0	5.9	4.0	6.0	1.4	0	2	-	-	-	-	-
Sulphide	mg/L	-	0.0026 to 0.036[d]	-	-	0.050	**0.030**[C]	**0.030**[C]	**0.037**[C]	**0.021**[C]	**0.038**[C]	0.012	0	2	-	100	-	-	-
Nutrients and Biological Indicators																			
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.33	0.33	0.45	0.20	0.46	0.18	0	2	-	-	-	-	-
Total ammonia	mg-N/L	-	0.14[e]	-	-	-	0.45	-	0.45	<0.05	0.45	-	1	2	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	1.7	1.7	1.7	1.6	1.7	0.071	0	2	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	2.0	2.0	2.1	1.9	2.1	0.11	0	2	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.040	0.040	0.049	0.030	0.050	0.014	0	2	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.023	0.023	0.032	0.012	0.033	0.015	0	2	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	<3.0	-	<3.0	<2.0	<3.0	-	2	2	-	-	-	-	-
General Organics																			
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	2	2	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-	**0.0065**[C, W]	**0.0065**[C, W]	**0.0079**[C, W]	**0.0050**[C, W]	**0.0080**[C, W]	0.0021	0	2	-	100	100	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	<2.0	<1.0	<2.0	-	2	2	-	-	-	-	-
Total Metals																			
Aluminum	μg/L	-	-	5,000	-	-	260	260	467	30	490	325	0	2	-	-	-	-	-
Antimony	μg/L	-	-	-	6.0	-	0.060	0.060	0.087	0.030	0.090	0.042	0	2	-	-	-	-	-
Arsenic	μg/L	-	5.0	25	10	-	1.2	1.2	1.7	0.50	1.8	0.92	0	2	-	-	-	-	-
Barium	μg/L	-	-	-	1,000	-	52	52	77	23	80	40	0	2	-	-	-	-	-
Beryllium	μg/L	-	-	100	-	-	0.080	-	0.080	<0.01	0.080	-	1	2	-	-	-	-	-
Boron	μg/L	29,000	1,500	5,000	5,000	-	180	180	288	60	300	170	0	2	-	-	-	-	-
Cadmium	μg/L	0.81 to 7.1[b]	0.073 to 0.37[b]	80	5.0	-	0.060	-	0.060	<0.006	0.060	-	1	2	-	-	-	-	-
Chromium	μg/L	-	1.0[h]	50	50[h]	-	**5.7**[C]	-	**5.7**[C]	<0.3	**5.7**[C]	-	1	2	-	50	-	-	-
Cobalt	μg/L	-	0.78 to 1.7[b]	1,000	-	-	0.91	0.91	1.6	0.10	**1.7**[C]	1.1	0	2	-	50	-	-	-
Copper	μg/L	6.4 to 51[b]	7.0[b]	500	-	1,000	1.3	1.3	2.2	0.20	2.3	1.5	0	2	-	-	-	-	-
Iron	μg/L	-	-	-	-	300	**2,000**[S]	**2,000**[S]	**2,900**[S]	**1,000**[S]	**3,000**[S]	1,414	0	2	-	-	-	-	100
Lead	μg/L	-	1.0 to 7.0[b]	100	10	-	0.89	0.89	1.7	0.030	1.7	1.2	0	2	-	-	-	-	-
Lithium	μg/L	-	-	-	-	-	23	23	35	10	36	18	0	2	-	-	-	-	-
Manganese	μg/L	-	-	-	-	50	**131**[S]	**131**[S]	**205**[S]	48	**213**[S]	117	0	2	-	-	-	-	50
Mercury	μg/L	0.013	0.0050	3.0	1.0	-	**0.0062**[C]	-	**0.0062**[C]	<0.0012	**0.0062**[C]	-	1	2	-	50	-	-	-
Methyl mercury	μg/L	0.0020	0.0010	-	-	-	<0.00003	-	<0.00003	-	-	-	1	1	-	-	-	-	-
Molybdenum	μg/L	-	73	500	-	-	0.28	0.28	0.44	0.10	0.46	0.25	0	2	-	-	-	-	-
Nickel	μg/L	212 to 1,288[b]	24 to 143[b]	1,000	-	-	3.7	-	3.7	<0.06	3.7	-	1	2	-	-	-	-	-
Selenium	μg/L	-	2.0	50	50	-	0.18	-	0.18	0.18	<0.3	-	1	2	-	-	-	-	-
Silver	μg/L	-	0.25	-	-	-	0.016	-	0.016	<0.005	0.016	-	1	2	-	-	-	-	-
Strontium	μg/L	-	-	-	-	-	155	155	196	110	200	64	0	2	-	-	-	-	-
Thallium	μg/L	-	0.80	-	-	-	0.0090	-	0.0090	<0.003	0.0090	-	1	2	-	-	-	-	-
Titanium	μg/L	-	-	-	-	-	6.4	6.4	10	1.9	11	6.4	0	2	-	-	-	-	-
Uranium	μg/L	33	15	200	20	-	0.63	0.63	1.2	0.051	1.2	0.82	0	2	-	-	-	-	-
Vanadium	μg/L	-	-	100	-	-	1.2	1.2	2.0	0.30	2.1	1.3	0	2	-	-	-	-	-
Zinc	μg/L	-	30	50,000	-	5,000	6.1	6.1	11	1.1	11	7.0	0	2	-	-	-	-	-
Dissolved Metals																			
Aluminum	μg/L	100[d]	50[d]	-	-	-	**202**[A, C]	**202**[A, C]	**378**[A, C]	5.0	**398**[A, C]	278	0	2	50	50	-	-	-
Antimony	μg/L	-	-	-	-	-	0.060	0.060	0.087	0.030	0.090	0.042	0	2	-	-	-	-	-
Arsenic	μg/L	-	-	-	-	-	0.90	0.90	1.3	0.50	1.3	0.57	0	2	-	-	-	-	-
Barium	μg/L	-	-	-	-	-	45	45	68	20	70	35	0	2	-	-	-	-	-
Beryllium	μg/L	-	-	-	-	-	0.040	-	0.040	<0.01	0.040	-	1	2	-	-	-	-	-
Boron	μg/L	-	-	-	-	-	185	185	307	50	320	191	0	2	-	-	-	-	-
Cadmium	μg/L	-	-	-	-	-	0.030	-	0.030	<0.006	0.030	-	1	2	-	-	-	-	-
Chromium	μg/L	-	-	-	-	-	3.6	-	3.6	<0.3	3.6	-	1	2	-	-	-	-	-
Cobalt	μg/L	-	-	-	-	-	0.79	0.79	1.4	0.080	1.5	1.0	0	2	-	-	-	-	-
Copper	μg/L	-	-	-	-	-	1.1	1.1	1.9	0.20	2.0	1.3	0	2	-	-	-	-	-
Iron	μg/L	-	300	-	-	-	**1,000**[C]	**1,000**[C]	**1,000**[C]	**1,000**[C]	**1,000**[C]	0	0	2	-	100	-	-	-
Lead	μg/L	-	-	-	-	-	0.33	0.33	0.59	0.030	0.62	0.42	0	2	-	-	-	-	-
Lithium	μg/L	-	-	-	-	-	26	26	39	10	41	22	0	2	-	-	-	-	-
Manganese	μg/L	-	-	-	-	-	136	136	230	32	240	147	0	2	-	-	-	-	-
Mercury	μg/L	-	-	-	-	-	0.0030	-	0.0030	0.0030	<0.05	-	1	2	-	-	-	-	-
Molybdenum	μg/L	-	-	-	-	-	0.34	0.34	0.56	0.10	0.58	0.34	0	2	-	-	-	-	-
Nickel	μg/L	-	-	-	-	-	3.8	-	3.8	<0.06	3.8	-	1	2	-	-	-	-	-
Selenium	μg/L	-	-	-	-	-	0.20	-	0.20	0.20	<0.3	-	1	2	-	-	-	-	-
Silver	μg/L	-	-	-	-	-	0.010	-	0.010	<0.005	0.010	-	1	2	-	-	-	-	-
Strontium	μg/L	-	-	-	-	-	160	160	214	100	220	85	0	2	-	-	-	-	-
Thallium	μg/L	-	-	-	-	-	0.0080	-	0.0080	<0.003	0.0080	-	1	2	-	-	-	-	-
Titanium	μg/L	-	-	-	-	-	5.0	5.0	8.1	1.4	8.5	5.0	0	2	-	-	-	-	-
Uranium	μg/L	-	-	-	-	-	0.67	0.67	1.2	0.048	1.3	0.89	0	2	-	-	-	-	-
Vanadium	μg/L	-	-	-	-	-	0.95	0.95	1.5	0.30	1.6	0.92	0	2	-	-	-	-	-
Zinc	μg/L	-	-	-	-	-	3.2	3.2	5.1	1.1	5.3	3.0	0	2	-	-	-	-	-

Parameter	Spring Median	Spring Mean	Spring 95th Percentile	Spring Minimum	Spring Maximum	Spring Standard Deviation	Spring nd	Spring Count	Spring % Above Guideline A	C	W	D	S	Summer Median	Summer Mean	Summer 95th Percentile	Summer Minimum	Summer Maximum	Summer Standard Deviation	Summer nd	Summer Count	Summer % Above Guideline A	C	W	D	S
Field Measured																										
pH	7.7	7.7	8.4	**6.8**[S]	8.5	1.2	0	2	-	-	-	-	50	8.5	-	8.5	-	-	-	0	1	-	-	-	-	-
Specific conductivity	102	102	107	96	108	8.5	0	2	-	-	-	-	-	160	-	160	-	-	-	0	1	-	-	-	-	-
Temperature	9.7	9.7	**16**[S]	2.4	**17**[S]	10	0	2	-	-	-	-	50	**20**[S]	-	**20**[S]	-	-	-	0	1	-	-	-	-	100
Dissolved oxygen	12	12	13	12	13	0.85	0	2	-	-	-	-	-	9.8	-	9.8	-	-	-	0	1	-	-	-	-	-
Conventional Parameters																										
pH	7.7	7.8	8.1	7.5	8.1	0.31	0	3	-	-	-	-	-	8.2	8.2	8.3	8.0	8.3	0.11	0	5	-	-	-	-	-
Specific conductivity	123	122	142	100	144	22	0	3	-	-	-	-	-	182	238	378	159	406	103	0	5	-	-	-	-	-
Hardness, as $CaCO_3$	50	49	58	39	59	10	0	3	-	-	-	-	-	85	107	162	74	171	42	0	5	-	-	-	-	-
Total alkalinity, as $CaCO_3$	54	56	67	46	68	11	0	3	-	-	-	-	-	93	124	210	80	228	62	0	5	-	-	-	-	-
Total dissolved solids	94	94	99	88	100	8.5	0	2	-	-	-	-	-	163	191	265	120	269	65	0	5	-	-	-	-	-
Total suspended solids	11	22	43	9.0	46	21	0	3	-	-	-	-	-	6.0	5.7	9.4	<3.0	10	3.2	1	5	-	-	-	-	-
Total organic carbon	23	22	26	18	26	4.0	0	3	-	-	-	-	-	25	26	33	22	34	4.8	0	5	-	-	-	-	-
Dissolved organic carbon	19	21	25	17	26	4.7	0	3	-	-	-	-	-	24	26	35	21	37	6.3	0	5	-	-	-	-	-
Colour	**120**[S]	**100**[S]	**129**[S]	**50**[S]	**130**[S]	44	0	3	-	-	-	-	100	**46**[S]	**72**[S]	**128**[S]	**25**[S]	**130**[S]	49	0	5	-	-	-	-	100
Major Ions																										
Bicarbonate	66	69	81	57	83	13	0	3	-	-	-	-	-	113	151	256	97	278	76	0	5	-	-	-	-	-
Calcium	13	13	15	11	15	2.0	0	3	-	-	-	-	-	20	25	36	18	38	8.5	0	5	-	-	-	-	-
Carbonate	<5.0	-	<5.0	<0.5	<5.0	-	3	3	-	-	-	-	-	<5.0	-	<5.0	<5.0	<5.0	-	5	5	-	-	-	-	-
Chloride	1.0	1.3	1.9	1.0	2.0	0.58	0	3	-	-	-	-	-	2.0	1.7	2.8	<1.0	3.0	0.97	1	5	-	-	-	-	-
Magnesium	4.4	4.4	5.2	3.6	5.3	0.85	0	3	-	-	-	-	-	7.6	9.6	14	7.2	15	3.4	0	5	-	-	-	-	-
Potassium	1.0	1.0	1.2	0.80	1.2	0.20	0	3	-	-	-	-	-	0.70	0.87	1.6	<0.5	1.8	0.58	1	5	-	-	-	-	-
Sodium	8.0	6.7	8.0	4.0	8.0	2.3	0	3	-	-	-	-	-	10	16	33	10	37	12	0	5	-	-	-	-	-
Sulphate	5.0	-	5.0	<1.0	5.0	-	1	3	-	-	-	-	-	6.0	5.4	7.6	2.0	8.0	2.2	0	5	-	-	-	-	-
Sulphide	<0.003	-	**0.0090**[C]	<0.002	**0.0090**[C]	-	2	3	-	33	-	-	-	0.0080	0.0092	**0.018**[C]	<0.002	**0.020**[C]	0.0069	1	5	-	20	-	-	-
Nutrients and Biological Indicators																										
Nitrate + nitrite	<0.1	-	<0.1	0.016	<0.1	-	2	3	-	-	-	-	-	<0.1	-	0.20	<0.1	0.20	-	4	5	-	-	-	-	-
Total ammonia	<0.05	-	<0.05	<0.05	<0.05	-	3	3	-	-	-	-	-	<0.05	-	0.070	<0.05	0.070	-	4	5	-	-	-	-	-
Total Kjeldahl nitrogen	0.90	1.1	1.6	0.80	1.7	0.49	0	3	-	-	-	-	-	1.2	1.2	1.8	0.70	1.9	0.43	0	5	-	-	-	-	-
Total nitrogen (calculated)	0.92	1.1	1.6	0.80	1.7	0.49	0	3	-	-	-	-	-	1.2	1.3	1.8	0.90	1.9	0.38	0	5	-	-	-	-	-
Total phosphorus	0.030	0.027	0.030	0.020	0.030	0.0058	0	3	-	-	-	-	-	0.040	0.038	0.056	0.020	0.060	0.015	0	5	-	-	-	-	-
Dissolved phosphorus	0.015	0.013	0.016	0.0070	0.016	0.0049	0	3	-	-	-	-	-	0.0090	0.016	0.036	0.0060	0.040	0.014	0	5	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	<3.0	<2.0	<3.0	-	3	3	-	-	-	-	-	<2.0	-	3.0	<2.0	3.0	-	4	5	-	-	-	-	-
General Organics																										
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	3	3	-	-	-	-	-	<1.0	-	1.0	<1.0	1.0	-	4	5	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0080**[C, W]	-	**0.0089**[C, W]	<0.002	**0.0090**[C, W]	-	1	3	-	67	67	-	-	**0.0080**[C, W]	**0.011**[C, W]	**0.020**[C, W]	**0.0060**[C, W]	**0.022**[C, W]	0.0066	0	5	-	100	100	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<1.0	<2.0	-	2	2	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	5	5	-	-	-	-	-
Total Metals																										
Aluminum	140	120	185	30	190	82	0	3	-	-	-	-	-	30	78	238	<20	290	119	1	5	-	-	-	-	-
Antimony	0.030	0.32	0.81	0.020	0.90	0.51	0	3	-	-	-	-	-	0.050	0.20	0.48	0.030	0.50	0.23	0	5	-	-	-	-	-
Arsenic	<0.4	-	0.50	0.30	0.50	-	1	3	-	-	-	-	-	0.40	-	1.2	<0.4	1.3	-	2	5	-	-	-	-	-
Barium	11	13	17	9.0	18	4.7	0	3	-	-	-	-	-	18	24	44	14	49	15	0	5	-	-	-	-	-
Beryllium	0.020	-	0.020	0.020	<1.0	-	1	3	-	-	-	-	-	0.020	-	<1.0	<0.01	<1.0	-	4	5	-	-	-	-	-
Boron	<50	-	60	40	60	-	1	3	-	-	-	-	-	50	74	148	40	170	54	0	5	-	-	-	-	-
Cadmium	0.010	-	0.010	<0.006	<0.2[DL>C]	-	2	3	-	-	-	-	-	0.010	-	0.010	<0.006	<0.2[DL>C]	-	2	4	-	-	-	-	-
Chromium	<0.3	-	<0.8	0.20	<0.8	-	2	3	-	-	-	-	-	0.50	-	<0.8	<0.3	<0.8	-	4	5	-	-	-	-	-
Cobalt	<0.2	-	0.33	0.10	0.33	-	1	3	-	-	-	-	-	<0.2	-	0.33	0.060	0.33	-	2	5	-	-	-	-	-
Copper	0.90	-	0.90	<0.1	<1.0	-	2	3	-	-	-	-	-	0.80	-	<1.0	<0.1	<1.0	-	3	5	-	-	-	-	-
Iron	250	**443**[S]	**925**[S]	80	**1,000**[S]	490	0	3	-	-	-	-	33	110	**460**[S]	**1,000**[S]	80	**1,000**[S]	493	0	5	-	-	-	-	40
Lead	<0.1	-	0.36	0.080	0.36	-	1	3	-	-	-	-	-	<0.1	-	0.19	0.030	0.19	-	2	5	-	-	-	-	-
Lithium	<6.0	-	6.0	3.0	6.0	-	1	3	-	-	-	-	-	7.0	7.8	13	<6.0	14	4.1	1	5	-	-	-	-	-
Manganese	12	18	31	9.0	33	13	0	3	-	-	-	-	-	36	40	**63**[S]	26	**69**[S]	17	0	5	-	-	-	-	20
Mercury	<0.0012	-	0.0040	<0.0006	0.0040	-	2	3	-	-	-	-	-	<0.0012	-	0.0020	<0.0006	0.0020	-	2	5	-	-	-	-	-
Methyl mercury	0.000080	-	0.000080	<0.00003	0.000080	-	1	2	-	-	-	-	-	<0.00003	-	<0.00003	<0.00003	<0.00003	-	2	2	-	-	-	-	-
Molybdenum	0.10	0.14	0.21	0.10	0.22	0.069	0	3	-	-	-	-	-	0.10	0.21	0.56	0.070	0.66	0.25	0	5	-	-	-	-	-
Nickel	0.40	-	0.85	<0.2	0.90	-	1	3	-	-	-	-	-	0.40	0.50	1.1	0.10	1.2	0.46	1	5	-	-	-	-	-
Selenium	<0.3	-	<0.4	0.040	<0.4	-	2	3	-	-	-	-	-	<0.3	-	<0.4	<0.3	<0.4	-	5	5	-	-	-	-	-
Silver	<0.005	-	0.026	<0.005	0.026	-	2	3	-	-	-	-	-	<0.005	-	0.014	0.0020	0.014	-	3	5	-	-	-	-	-
Strontium	40	43	58	30	60	15	0	3	-	-	-	-	-	70	90	130	60	130	37	0	5	-	-	-	-	-
Thallium	0.0030	-	0.0030	<0.003	<0.1	-	2	3	-	-	-	-	-	0.0070	-	<0.1	<0.003	<0.1	-	4	5	-	-	-	-	-
Titanium	4.6	-	4.6	3.0	<5.0	-	1	3	-	-	-	-	-	<5.0	-	9.2	1.3	9.2	-	2	5	-	-	-	-	-
Uranium	0.062	-	0.062	0.025	<0.1	-	1	3	-	-	-	-	-	<0.1	-	0.41	0.016	0.41	-	2	5	-	-	-	-	-
Vanadium	0.50	-	0.68	<0.2	0.70	-	1	3	-	-	-	-	-	0.50	0.62	1.1	0.30	1.2	0.34	0	5	-	-	-	-	-
Zinc	2.9	-	2.9	0.20	<4.0	-	1	3	-	-	-	-	-	<4.0	-	4.8	0.40	4.8	-	2	5	-	-	-	-	-
Dissolved Metals																										
Aluminum	17	-	20	<10	20	-	1	3	-	-	-	-	-	<10	-	20	2.0	20	-	2	5	-	-	-	-	-
Antimony	0.030	-	0.72	<0.02	0.80	-	1	3	-	-	-	-	-	0.050	0.26	0.60	0.030	0.60	0.31	0	5	-	-	-	-	-
Arsenic	0.30	-	0.30	0.30	<0.4	-	1	3	-	-	-	-	-	0.40	0.52	0.92	<0.4	1.0	0.30	1	5	-	-	-	-	-
Barium	10	13	19	10	20	5.8	0	3	-	-	-	-	-	20	24	44	10	50	15	0	5	-	-	-	-	-
Beryllium	<0.01	-	<0.5	<0.01	<0.5	-	3	3	-	-	-	-	-	0.010	-	<0.5	<0.01	<0.5	-	4	5	-	-	-	-	-
Boron	<50	-	50	40	50	-	1	3	-	-	-	-	-	50	70	146	40	170	56	0	5	-	-	-	-	-
Cadmium	<0.006	-	<0.1	<0.005	<0.1	-	3	3	-	-	-	-	-	0.010	-	<0.1	<0.006	<0.1	-	4	5	-	-	-	-	-
Chromium	<0.3	-	1.0	<0.1	1.0	-	2	3	-	-	-	-	-	<0.3	-	0.90	<0.3	0.90	-	4	5	-	-	-	-	-
Cobalt	0.15	0.31	0.65	0.070	0.70	0.34	0	3	-	-	-	-	-	0.22	0.63	1.6	0.030	1.7	0.74	0	5	-	-	-	-	-
Copper	0.60	-	0.78	<0.1	0.80	-	1	3	-	-	-	-	-	<0.6	-	0.68	<0.1	0.70	-	2	5	-	-	-	-	-
Iron	135	135	215	46	224	89	0	3	-	-	-	-	-	16	287	**879**[C]	11	**1,000**[C]	431	0	5	-	40	-	-	-
Lead	0.070	-	0.070	0.030	<0.1	-	1	3	-	-	-	-	-	<0.1	0.066	0.14	0.010	0.15	0.059	1	5	-	-	-	-	-
Lithium	5.0	4.7	5.0	4.0	5.0	0.58	0	3	-	-	-	-	-	6.0	7.6	12	5.0	13	3.4	0	5	-	-	-	-	-
Manganese	2.5	7.8	17	2.0	19	9.7	0	3	-	-	-	-	-	4.0	11	30	0.50	34	14	0	5	-	-	-	-	-
Mercury	0.0020	-	0.0020	<0.0006	<0.05	-	2	3	-	-	-	-	-	<0.05	-	<0.05	<0.0006	<0.05	-	5	5	-	-	-	-	-
Molybdenum	0.12	0.12	0.14	0.10	0.14	0.020	0	3	-	-	-	-	-	0.12	0.22	0.56	0.070	0.65	0.25	1	5	-	-	-	-	-
Nickel	0.40	0.37	0.58	0.10	0.60	0.25	0	3	-	-	-	-	-	0.40	0.49	1.0	<0.1	1.1	0.45	1	5	-	-	-	-	-
Selenium	<0.3	-	<0.4	<0.04	<0.4	-	3	3	-	-	-	-	-	<0.3	-	0.40	<0.3	0.40	-	4	5	-	-	-	-	-
Silver	<0.005	-	<0.2	<0.005	<0.2	-	3	3	-	-	-	-	-	<0.005	-	<0.005	<0.0005	<0.005	-	4	4	-	-	-	-	-
Strontium	40	40	49	30	50	10	0	3	-	-	-	-	-	70	88	128	60	130	34	0	5	-	-	-	-	-
Thallium	<0.003	-	<0.05	<0.002	<0.05	-	3	3	-	-	-	-	-	0.0040	-	<0.05	0.0020	<0.05	-	3	5	-	-	-	-	-
Titanium	<0.5	-	0.70	0.30	0.70	-	1	3	-	-	-	-	-	0.80	1.1	2.5	<0.3	2.9	1.1	1	5	-	-	-	-	-
Uranium	0.030	-	0.030	0.018	<0.1	-	1	3	-	-	-	-	-	<0.1	-	0.39	0.013	0.39	-	2	5	-	-	-	-	-
Vanadium	0.30	0.27	0.30	0.20	0.30	0.058	0	3	-	-	-	-	-	0.20	0.27	0.48	<0.1	0.50	0.18	1	5	-	-	-	-	-
Zinc	3.0	2.1	3.2	0.20	3.2	1.7	0	3	-	-	-	-	-	<2.0	1.9	3.6	0.40	3.8	1.4	1	5	-	-	-	-	-

Table V-3: Baseline Phase Seasonal Water Quality Data from the Muskeg Creek Watershed Compared to Guidelines, 2006 to 2010

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
										A	C	W	D	S
Field Measured														
pH	-	7.7	7.7	7.9	7.4	7.9	0.24	0	4	-	-	-	-	-
Specific conductivity	µS/cm	165	169	202	140	206	31	0	4	-	-	-	-	-
Temperature	°C	8.4	8.9	11	7.1	12	2.0	0	4	-	-	-	-	-
Dissolved oxygen	mg/L	9.4	9.9	11	9.0	11	1.2	0	3	-	-	-	-	-
Conventional Parameters														
pH	-	8.1	8.1	8.3	7.9	8.3	0.13	0	10	-	-	-	-	-
Specific conductivity	µS/cm	175	178	219	134	231	29	0	10	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	77	80	101	69	107	12	0	10	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	88	89	113	64	121	16	0	10	-	-	-	-	-
Total dissolved solids	mg/L	155	161	198	134	220	24	0	10	-	-	-	-	-
Total suspended solids	mg/L	5.0	-	24	<3.0	29	-	3	10	-	-	-	-	-
Total organic carbon	mg/L	29	27	32	9.8	32	6.7	0	10	-	-	-	-	-
Dissolved organic carbon	mg/L	25	24	34	9.8	34	7.9	0	10	-	-	-	-	-
Colour	TCU	**87**[(S)]	**91**[(S)]	**169**[(S)]	**27**[(S)]	**170**[(S)]	59	0	10	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	107	109	139	79	148	20	0	10	-	-	-	-	-
Calcium	mg/L	19	19	23	16	23	2.3	0	10	-	-	-	-	-
Carbonate	mg/L	<5.0	-	<5.0	<5.0	<5.0	-	10	10	-	-	-	-	-
Chloride	mg/L	1.0	-	2.6	<1.0	3.0	-	4	10	-	-	-	-	-
Magnesium	mg/L	6.6	7.1	9.1	5.7	9.7	1.2	0	10	-	-	-	-	-
Potassium	mg/L	<0.5	-	1.2	<0.5	1.5	-	6	10	-	-	-	-	-
Sodium	mg/L	9.5	11	18	5.0	18	4.1	0	10	-	-	-	-	-
Sulphate	mg/L	3.5	3.2	4.6	2.0	5.0	1.1	0	10	-	-	-	-	-
Sulphide	mg/L	0.0070	0.0096	**0.022**[(C)]	0.0020	**0.025**[(C)]	0.0073	0	10	-	30	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.1	-	<0.1	<0.071	<0.1	-	10	10	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	0.24	<0.05	0.24	-	9	10	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	1.2	1.3	1.9	0.80	1.9	0.42	0	10	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	1.2	1.3	1.9	0.80	1.9	0.42	0	10	-	-	-	-	-
Total phosphorus	mg-P/L	0.030	0.030	0.040	0.020	0.040	0.0093	0	8	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.010	0.012	0.026	0.0040	0.031	0.0089	0	8	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	2.1	<2.0	2.2	-	7	10	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	<1.0	-	<1.0	0.090	<1.0	-	7	10	-	-	-	-	-
Phenol[(f)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(g)]	mg/L	**0.0090**[(C, W)]	**0.0083**[(C, W)]	**0.013**[(C, W)]	<0.001	**0.016**[(C, W)]	0.0039	1	10	-	90	90	-	-
Total recoverable hydrocarbons	mg/L	<1.0	-	<1.0	<1.0	<1.0	-	10	10	-	-	-	-	-
Total Metals														
Aluminum	µg/L	25	226	1,000	10	1,000	409	0	10	-	-	-	-	-
Antimony	µg/L	0.030	0.16	1.4	0.020	1.4	0.43	2	10	-	-	-	-	-
Arsenic	µg/L	0.45	0.53	0.80	0.30	0.80	0.18	0	10	-	-	-	-	-
Barium	µg/L	15	18	26	12	26	5.6	0	10	-	-	-	-	-
Beryllium	µg/L	0.010	-	<1.0	<0.01	<1.0	-	8	10	-	-	-	-	-
Boron	µg/L	50	44	56	20	60	12	0	10	-	-	-	-	-
Cadmium	µg/L	<0.006	-	<0.2[(DL>C)]	<0.006	<0.2[(DL>C)]	-	9	10	-	-	-	-	-
Chromium	µg/L	<0.3	-	**1.7**[(C)]	0.10	**2.0**[(C)]	-	6	10	-	30	-	-	-
Cobalt	µg/L	0.080	0.13	0.39	0.020	0.42	0.14	2	10	-	-	-	-	-
Copper	µg/L	0.30	0.36	0.70	<0.1	<1.0	0.24	2	10	-	-	-	-	-
Iron	µg/L	195	**403**[(S)]	**1,000**[(S)]	70	**1,000**[(S)]	420	0	10	-	-	-	-	30
Lead	µg/L	0.090	0.11	0.38	0.010	0.39	0.14	2	10	-	-	-	-	-
Lithium	µg/L	6.0	6.1	8.6	3.0	9.0	1.8	0	10	-	-	-	-	-
Manganese	µg/L	27	26	39	9.0	41	10	0	10	-	-	-	-	-
Mercury	µg/L	<0.0012	-	**0.050**[(A, C)]	<0.0006	**0.050**[(A, C)]	-	5	10	20	20	-	-	-
Methyl mercury	µg/L	0.000050	-	0.000050	-	-	-	0	1	-	-	-	-	-
Molybdenum	µg/L	0.11	0.097	0.20	0.030	0.20	0.063	1	10	-	-	-	-	-
Nickel	µg/L	0.25	0.42	1.0	<0.06	1.1	0.38	2	10	-	-	-	-	-
Selenium	µg/L	<0.3	-	0.90	<0.2	0.90	-	9	10	-	-	-	-	-
Silver	µg/L	<0.005	-	0.018	0.0030	0.018	-	7	10	-	-	-	-	-
Strontium	µg/L	70	69	86	50	90	12	0	10	-	-	-	-	-
Thallium	µg/L	<0.003	-	<0.1	<0.003	<0.1	-	9	10	-	-	-	-	-
Titanium	µg/L	1.5	5.6	21	0.60	22	8.2	1	10	-	-	-	-	-
Uranium	µg/L	0.045	-	<0.1	0.0040	<0.1	-	3	10	-	-	-	-	-
Vanadium	µg/L	0.45	0.79	2.3	0.20	2.4	0.82	0	10	-	-	-	-	-
Zinc	µg/L	1.4	2.0	4.5	<0.2	5.0	1.8	1	10	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	6.0	-	40	<1.0	44	-	3	10	-	-	-	-	-
Antimony	µg/L	0.030	0.094	0.70	0.020	0.70	0.21	2	10	-	-	-	-	-
Arsenic	µg/L	0.40	0.42	0.61	0.30	0.70	0.12	0	10	-	-	-	-	-
Barium	µg/L	10	14	20	10	20	5.2	0	10	-	-	-	-	-
Beryllium	µg/L	<0.01	-	<0.5	<0.01	<0.5	-	9	10	-	-	-	-	-
Boron	µg/L	50	43	56	20	60	13	0	10	-	-	-	-	-
Cadmium	µg/L	<0.006	-	<0.1	<0.006	<0.1	-	10	10	-	-	-	-	-
Chromium	µg/L	<0.3	-	0.52	0.10	0.70	-	7	10	-	-	-	-	-
Cobalt	µg/L	0.075	0.078	0.21	0.020	0.30	0.083	2	10	-	-	-	-	-
Copper	µg/L	0.35	0.31	0.50	0.10	<0.6	0.14	1	10	-	-	-	-	-
Iron	µg/L	98	201	**685**[(C)]	<4.0	**1,000**[(C)]	306	1	10	-	20	-	-	-
Lead	µg/L	0.025	-	<0.1	<0.006	<0.1	-	5	10	-	-	-	-	-
Lithium	µg/L	6.0	5.7	8.6	2.0	9.0	2.2	0	10	-	-	-	-	-
Manganese	µg/L	1.1	1.8	4.7	0.20	4.8	1.8	1	10	-	-	-	-	-
Mercury	µg/L	<0.05	-	<0.05	<0.0006	<0.05	-	10	10	-	-	-	-	-
Molybdenum	µg/L	0.090	0.083	0.16	0.030	0.19	0.051	1	10	-	-	-	-	-
Nickel	µg/L	0.25	0.32	0.60	<0.06	0.60	0.24	2	10	-	-	-	-	-
Selenium	µg/L	<0.3	-	<0.4	<0.2	<0.4	-	10	10	-	-	-	-	-
Silver	µg/L	<0.005	-	0.010	<0.005	0.010	-	9	10	-	-	-	-	-
Strontium	µg/L	70	65	81	40	90	14	0	10	-	-	-	-	-
Thallium	µg/L	<0.003	-	<0.1	0.0020	<0.1	-	9	10	-	-	-	-	-
Titanium	µg/L	0.75	1.0	2.0	<0.3	2.0	0.68	1	10	-	-	-	-	-
Uranium	µg/L	0.028	-	<0.1	0.0030	<0.1	-	3	10	-	-	-	-	-
Vanadium	µg/L	0.30	0.28	0.46	0.10	0.50	0.13	0	10	-	-	-	-	-
Zinc	µg/L	1.1	1.6	4.2	0.20	5.0	1.5	0	10	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.

(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (39 to 330 mg/L). The guideline is calculated based on the individual hardness value for each sample.

(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.

(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (6.8 to 8.5). The guideline is calculated based on the individual pH for each sample.

(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.14 mg-N/L) is presented and was calculated based on the combination of field pH (8.5) and water temperature (19.9°C). The guideline is calculated based on the individual field pH and temperature measurements for each sample.

(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.

(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.

(h) Guideline is for chromium VI.

A = Concentration is higher than the acute aquatic life GOA (2018) guideline.

C = Concentration is higher than the chronic aquatic life GOA (2018) guideline.

W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.

S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.

DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.

Notes: **Bolded** concentrations are higher than water quality guidelines.

In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.

- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit.

Table V-4: Operational Phase Seasonal Water Quality Data from the Muskeg Creek Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of: Aquatic Life – Acute	Aquatic Life – Chronic	Wildlife Health (Livestock)	Health Canada (2017) Drinking Water MAC	Drinking Water AO	Seasonal Summary – Winter: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.3	7.3	7.8	**6.9**[S]	8.0	0.39	0	6	-	-	-	-	17
Specific conductivity	µS/cm	-	-	-	-	-	345	471	802	283	821	244	0	6	-	-	-	-	-
Temperature	°C	-	-	-	-	15	0.26	0.48	1.2	-0.1	1.3	0.60	0	6	-	-	-	-	-
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	**3.0**[A, C]	**5.4**[C]	12	**1.9**[A, C]	13	4.5	0	6	67	67	-	-	-
Conventional Parameters																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.9	7.9	8.4	7.6	8.4	0.34	0	6	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	325	478	863	280	900	273	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	151	171	240	129	246	51	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-	160	240	448	130	470	147	0	6	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	255	307	**505**[S]	190	**540**[S]	137	0	6	-	-	-	-	17
Total suspended solids	mg/L	-	-	-	-	-	1.1	-	12	<1.0	16	-	3	6	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	29	29	39	19	41	7.1	0	6	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	30	29	38	19	40	6.9	0	6	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**68**[S]	**67**[S]	**97**[S]	**30**[S]	**99**[S]	26	0	6	-	-	-	-	100
Major Ions																			
Bicarbonate	mg/L	-	-	-	-	-	190	288	535	160	560	175	0	6	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	39	44	59	34	59	12	0	6	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<1.0	-	6.6	<0.5	6.6	-	5	6	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	2.8	2.8	3.5	2.3	3.6	0.48	0	6	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	12	16	24	10	24	6.4	0	6	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	2.0	2.1	2.8	1.6	3.0	0.50	0	6	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	16	46	113	13	117	49	0	6	-	-	-	-	-
Sulphate	mg/L	-	218[b]	1,000	-	500	3.3	-	17	<1.0	19	-	2	6	-	-	-	-	-
Sulphide	mg/L	-	0.0019 to 2.7[c]	-	-	0.050	0.0027	-	**0.029**[C]	<0.0019	**0.035**[C]	-	3	6	-	33	-	-	-
Nutrients and Biological Indicators																			
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.052	0.051	0.084	<0.02	0.086	0.031	1	6	-	-	-	-	-
Total ammonia	mg-N/L	-	0.019[d]	-	-	-	0.21	0.24	0.50	0.026	0.51	0.21	0	6	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	1.1	1.2	2.0	0.54	2.0	0.63	0	6	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	1.1	1.3	2.0	0.62	2.0	0.61	0	6	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.027	0.036	0.072	0.0060	0.074	0.030	0	6	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.0055	0.0094	0.022	<0.001	0.022	0.0098	1	6	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	<2.0	-	2.5	<2.0	2.5	-	5	6	-	-	-	-	-
General Organics																			
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	6	6	-	-	-	-	-
Phenol[e]	mg/L	-	0.0040	0.0020	-	-	**0.0033**[W]	-	**0.0033**[W]	<0.002	**0.0033**[W]	-	1	2	-	-	50	-	-
Total phenolics[f]	mg/L	-	0.0040	0.0020	-	-	**0.0057**[C, W]	-	**0.0079**[C, W]	<0.002	**0.0080**[C, W]	-	1	4	-	75	75	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	<2.0	<2.0	<2.0	-	6	6	-	-	-	-	-
Total Metals																			
Aluminum	µg/L	-	-	5,000	-	-	15	18	39	3.8	44	15	0	6	-	-	-	-	-
Antimony	µg/L	-	-	-	6.0	-	0.041	0.038	0.051	<0.02	0.051	0.015	1	6	-	-	-	-	-
Arsenic	µg/L	-	5.0	25	10	-	0.45	0.49	0.76	0.33	0.82	0.18	0	6	-	-	-	-	-
Barium	µg/L	-	-	-	1,000	-	38	39	53	29	55	9.9	0	6	-	-	-	-	-
Beryllium	µg/L	-	-	100	-	-	<0.01	-	<0.01	<0.01	<0.01	-	6	6	-	-	-	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-	62	176	420	45	423	186	0	6	-	-	-	-	-
Cadmium	µg/L	1.1 to 5.2[b]	0.093 to 0.33[b]	80	5.0	-	0.0080	-	0.010	<0.005	0.011	-	3	6	-	-	-	-	-
Chromium	µg/L	-	1.0[u]	50	50[u]	-	<0.1	-	0.13	<0.1	0.13	-	4	6	-	-	-	-	-
Cobalt	µg/L	-	0.78 to 1.5[b]	1,000	-	-	0.092	0.17	0.45	0.032	0.52	0.19	0	6	-	-	-	-	-
Copper	µg/L	8.6 to 39[b]	7.0[b]	500	-	1,000	0.44	0.67	1.8	0.11	2.1	0.74	0	6	-	-	-	-	-
Iron	µg/L	-	-	-	-	300	**978**[S]	**955**[S]	**1,350**[S]	**334**[S]	**1,440**[S]	358	0	6	-	-	-	-	100
Lead	µg/L	-	1.0 to 7.0[b]	100	10	-	0.043	0.083	0.23	0.0080	0.28	0.10	0	6	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	11	16	29	8.9	31	9.5	0	6	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50	**179**[S]	**164**[S]	**263**[S]	49	**270**[S]	90	0	6	-	-	-	-	83
Mercury	µg/L	0.013	0.0050	3.0	1.0	-	0.0014	0.0015	0.0026	0.00054	0.0028	0.00087	0	6	-	-	-	-	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-	0.00012	-	0.00028	<0.00008	0.00032	-	2	6	-	-	-	-	-
Molybdenum	µg/L	-	73	500	-	-	0.11	0.45	1.2	0.062	1.3	0.56	0	6	-	-	-	-	-
Nickel	µg/L	274 to 1,005[b]	30 to 112[b]	1,000	-	-	0.51	0.61	1.2	0.16	1.3	0.46	0	6	-	-	-	-	-
Selenium	µg/L	-	2.0	50	50	-	0.064	0.065	0.089	0.041	0.092	0.020	0	6	-	-	-	-	-
Silver	µg/L	-	0.25	-	-	-	<0.005	-	0.0050	<0.005	<0.01	-	5	6	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	112	131	184	100	190	38	0	6	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-	0.0020	-	0.0027	<0.002	0.0028	-	3	6	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	0.98	-	1.4	<0.5	<2.0	-	3	6	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-	0.069	0.32	1.0	0.013	1.2	0.47	0	6	-	-	-	-	-
Vanadium	µg/L	-	-	100	-	-	0.23	-	0.41	<0.2	0.46	-	3	6	-	-	-	-	-
Zinc	µg/L	-	30	50,000	-	5,000	2.5	3.5	6.9	1.4	7.4	2.4	0	6	-	-	-	-	-
Dissolved Metals																			
Aluminum	µg/L	20 to 100[c]	5.1 to 50[c]	-	-	-	2.8	3.5	7.7	1.2	9.0	2.8	0	6	-	-	-	-	-
Antimony	µg/L	-	-	-	-	-	0.033	0.031	0.045	<0.02	0.048	0.013	1	6	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-	0.44	0.47	0.64	0.36	0.69	0.12	0	6	-	-	-	-	-
Barium	µg/L	-	-	-	-	-	36	37	48	28	50	8.4	0	6	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-	<0.01	-	0.011	<0.01	0.011	-	5	6	-	-	-	-	-
Boron	µg/L	-	-	-	-	-	62	171	413	52	427	177	0	6	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-	<0.005	-	0.010	<0.005	0.010	-	5	6	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	-	6	6	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-	0.072	0.16	0.44	0.032	0.50	0.18	0	6	-	-	-	-	-
Copper	µg/L	-	-	-	-	-	0.27	0.28	0.56	<0.05	0.62	0.22	1	6	-	-	-	-	-
Iron	µg/L	-	300	-	-	-	**512**[C]	**554**[C]	**1,015**[C]	239	**1,140**[C]	334	0	6	-	67	-	-	-
Lead	µg/L	-	-	-	-	-	0.0099	-	0.033	<0.005	0.034	-	2	6	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	12	17	30	9.5	33	9.5	0	6	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-	129	134	255	35	277	92	0	6	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-	0.00095	0.0014	0.0037	0.00023	0.0045	0.0016	0	6	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-	0.12	0.44	1.2	0.053	1.3	0.55	0	6	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-	0.38	0.58	1.3	0.16	1.4	0.50	0	6	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-	0.060	0.069	0.11	0.042	0.12	0.032	0	6	-	-	-	-	-
Silver	µg/L	-	-	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	6	6	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	119	134	185	96	187	40	0	6	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-	<0.002	-	<0.002	<0.002	<0.002	-	6	6	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	<0.5	-	0.76	<0.5	0.76	-	5	6	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-	0.060	0.32	1.0	0.013	1.2	0.47	0	6	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-	<0.2	-	<0.2	<0.2	<0.2	-	6	6	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-	1.9	2.3	4.1	0.80	4.1	1.5	0	6	-	-	-	-	-

Parameter	Seasonal Summary – Spring: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.9	7.6	8.5	**4.1**[C, S]	8.5	1.3	0	10	-	10	-	-	10
Specific conductivity	193	242	532	122	631	158	0	10	-	-	-	-	-
Temperature	5.3	7.6	**19**[S]	-3.3	**20**[S]	8.9	0	10	-	-	-	-	40
Dissolved oxygen	11	9.9	14	**2.4**[A, C]	14	3.4	0	10	10	10	-	-	-
Conventional Parameters													
pH	8.0	8.0	8.3	7.9	8.3	0.14	0	10	-	-	-	-	-
Specific conductivity	175	204	373	120	440	97	0	10	-	-	-	-	-
Hardness, as $CaCO_3$	83	90	147	53	160	33	0	10	-	-	-	-	-
Total alkalinity, as $CaCO_3$	84	97	184	53	220	50	0	10	-	-	-	-	-
Total dissolved solids	140	155	239	110	270	48	0	10	-	-	-	-	-
Total suspended solids	2.3	25	100	<1.0	130	43	2	10	-	-	-	-	-
Total organic carbon	20	20	25	16	27	3.2	0	10	-	-	-	-	-
Dissolved organic carbon	19	20	24	16	26	2.7	0	10	-	-	-	-	-
Colour	**50**[S]	**51**[S]	**89**[S]	**21**[S]	**100**[S]	27	0	10	-	-	-	-	100
Major Ions													
Bicarbonate	101	118	225	64	270	62	0	10	-	-	-	-	-
Calcium	22	23	38	13	40	8.7	0	10	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	10	10	-	-	-	-	-
Chloride	2.1	2.3	3.8	1.2	4.0	0.99	0	10	-	-	-	-	-
Magnesium	7.0	7.5	12	4.7	14	2.8	0	10	-	-	-	-	-
Potassium	1.3	1.3	1.8	0.82	1.8	0.35	0	10	-	-	-	-	-
Sodium	9.3	12	30	4.6	44	11	0	10	-	-	-	-	-
Sulphate	<1.0	-	4.0	<1.0	4.0	-	9	10	-	-	-	-	-
Sulphide	0.0025	-	**0.0054**[C]	<0.0019	**0.0060**[C]	-	5	10	-	20	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	0.019	-	0.092	<0.01	0.14	-	5	10	-	-	-	-	-
Total ammonia	<0.05	-	0.13	<0.015	0.18	-	5	10	-	-	-	-	-
Total Kjeldahl nitrogen	0.68	0.76	1.1	0.50	1.1	0.19	0	10	-	-	-	-	-
Total nitrogen (calculated)	0.75	0.78	1.1	0.50	1.1	0.20	0	10	-	-	-	-	-
Total phosphorus	0.030	0.033	0.081	0.0080	0.10	0.028	0	10	-	-	-	-	-
Dissolved phosphorus	0.013	0.016	0.037	0.0030	0.042	0.013	0	10	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	2.4	<2.0	2.6	-	8	10	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	10	10	-	-	-	-	-
Phenol[e]	<0.002	-	**0.0040**[C, W]	<0.002	**0.0045**[C, W]	-	3	5	-	20	40	-	-
Total phenolics[f]	**0.0053**[C, W]	**0.0054**[C, W]	**0.0068**[C, W]	**0.0040**[W]	**0.0071**[C, W]	0.0011	0	5	-	80	100	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	10	10	-	-	-	-	-
Total Metals													
Aluminum	32	198	781	4.5	1,000	325	0	10	-	-	-	-	-
Antimony	0.029	-	0.048	<0.02	0.050	-	4	10	-	-	-	-	-
Arsenic	0.42	0.48	0.93	0.24	1.0	0.26	0	10	-	-	-	-	-
Barium	23	22	31	9.5	32	8.3	0	10	-	-	-	-	-
Beryllium	<0.01	-	0.064	<0.01	0.068	-	6	10	-	-	-	-	-
Boron	40	-	117	29	170	-	3	10	-	-	-	-	-
Cadmium	0.0050	-	0.041	<0.005	0.050	-	4	10	-	-	-	-	-
Chromium	0.11	-	0.98	<0.1	**1.2**[C]	-	4	10	-	10	-	-	-
Cobalt	0.12	0.30	**1.0**[C]	0.024	**1.1**[C]	0.39	0	10	-	20	-	-	-
Copper	0.34	0.55	1.6	0.067	1.7	0.60	0	10	-	-	-	-	-
Iron	**750**[S]	**872**[S]	**2,586**[S]	37	**3,000**[S]	974	0	10	-	-	-	-	60
Lead	0.069	0.27	1.1	0.024	**1.3**[C]	0.42	0	10	-	10	-	-	-
Lithium	6.1	7.1	13	4.2	14	3.1	0	10	-	-	-	-	-
Manganese	35	**72**[S]	**163**[S]	18	**181**[S]	62	0	10	-	-	-	-	40
Mercury	0.00084	0.0027	**0.0081**[C]	<0.0006	**0.0088**[C]	0.0030	1	10	-	20	-	-	-
Methyl mercury	0.000080	-	0.00015	<0.00008	0.00015	-	5	10	-	-	-	-	-
Molybdenum	0.11	0.16	0.43	<0.05	0.57	0.17	2	10	-	-	-	-	-
Nickel	0.55	0.79	2.1	0.14	2.2	0.74	0	10	-	-	-	-	-
Selenium	0.044	-	0.067	<0.04	0.080	-	3	10	-	-	-	-	-
Silver	<0.005	-	0.014	<0.005	0.014	-	8	10	-	-	-	-	-
Strontium	58	66	106	41	110	23	0	10	-	-	-	-	-
Thallium	0.0020	-	0.015	<0.002	0.020	-	5	10	-	-	-	-	-
Titanium	1.5	-	19	<0.5	22	-	3	10	-	-	-	-	-
Uranium	0.058	0.11	0.32	0.013	0.42	0.13	0	10	-	-	-	-	-
Vanadium	0.28	-	2.4	<0.2	2.6	-	4	10	-	-	-	-	-
Zinc	2.4	5.0	15	0.12	21	6.3	0	10	-	-	-	-	-
Dissolved Metals													
Aluminum	12	10	20	1.2	21	7.2	0	10	-	10	-	-	-
Antimony	0.027	-	0.042	<0.02	0.046	-	3	10	-	-	-	-	-
Arsenic	0.34	0.34	0.48	0.24	0.50	0.090	0	10	-	-	-	-	-
Barium	16	19	32	9.0	33	7.4	0	10	-	-	-	-	-
Beryllium	<0.01	-	<0.01	<0.01	<0.01	-	10	10	-	-	-	-	-
Boron	40	-	128	26	190	-	3	10	-	-	-	-	-
Cadmium	<0.005	-	0.016	<0.005	0.020	-	7	10	-	-	-	-	-
Chromium	<0.1	-	0.11	<0.1	0.12	-	8	10	-	-	-	-	-
Cobalt	0.082	0.11	0.28	0.017	0.30	0.10	0	10	-	-	-	-	-
Copper	0.28	0.55	2.1	<0.05	3.5	1.0	1	10	-	-	-	-	-
Iron	158	282	**777**[C]	8.9	**790**[C]	298	0	10	-	40	-	-	-
Lead	0.028	0.036	0.087	<0.005	0.090	0.032	2	10	-	-	-	-	-
Lithium	6.4	7.0	13	3.7	15	3.4	0	10	-	-	-	-	-
Manganese	14	39	128	0.13	150	54	0	10	-	-	-	-	-
Mercury	0.00071	0.0011	0.0024	0.00022	0.0024	0.00091	1	10	-	-	-	-	-
Molybdenum	0.12	0.17	0.44	<0.05	0.58	0.17	1	10	-	-	-	-	-
Nickel	0.48	0.45	0.76	0.12	0.80	0.28	0	10	-	-	-	-	-
Selenium	0.040	-	0.081	<0.04	0.10	-	5	10	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	10	10	-	-	-	-	-
Strontium	59	64	106	35	110	25	0	10	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	8	10	-	-	-	-	-
Titanium	0.73	-	1.5	<0.5	1.6	-	5	10	-	-	-	-	-
Uranium	0.047	0.082	0.28	0.013	0.41	0.12	0	10	-	-	-	-	-
Vanadium	0.25	-	0.32	<0.2	0.34	-	3	10	-	-	-	-	-
Zinc	0.70	2.2	7.7	0.19	11	3.3	0	10	-	-	-	-	-

Parameter	Seasonal Summary – Summer: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.9	8.4	**10**[C]	7.6	**10**[C]	1.1	0	6	-	17	-	-	-
Specific conductivity	194	243	418	142	459	117	0	6	-	-	-	-	-
Temperature	14	14	**18**[S]	11	**19**[S]	3.2	0	6	-	-	-	-	33
Dissolved oxygen	9.5	9.1	10	7.2	10	1.2	0	6	-	-	-	-	-
Conventional Parameters													
pH	8.2	8.1	8.4	7.8	8.4	0.23	0	6	-	-	-	-	-
Specific conductivity	200	263	440	170	460	125	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	103	119	170	79	170	41	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	99	133	223	81	230	65	0	6	-	-	-	-	-
Total dissolved solids	180	195	268	140	270	57	0	6	-	-	-	-	-
Total suspended solids	2.7	-	30	<1.0	37	-	2	6	-	-	-	-	-
Total organic carbon	22	22	25	19	26	2.4	0	6	-	-	-	-	-
Dissolved organic carbon	21	21	24	18	24	1.9	0	6	-	-	-	-	-
Colour	**87**[S]	**76**[S]	**114**[S]	**24**[S]	**120**[S]	36	0	6	-	-	-	-	100
Major Ions													
Bicarbonate	120	162	270	99	280	78	0	6	-	-	-	-	-
Calcium	27	31	44	20	45	11	0	6	-	-	-	-	-
Carbonate	<0.5	-	3.0	<0.5	3.0	-	5	6	-	-	-	-	-
Chloride	2.2	2.4	3.2	1.4	3.3	0.69	0	6	-	-	-	-	-
Magnesium	8.7	10	15	6.9	15	3.4	0	6	-	-	-	-	-
Potassium	0.84	0.80	1.2	0.35	1.2	0.33	0	6	-	-	-	-	-
Sodium	9.7	17	39	6.5	43	15	0	6	-	-	-	-	-
Sulphate	1.6	-	4.0	<1.0	<10	-	4	6	-	-	-	-	-
Sulphide	<0.0019	-	0.0047	<0.0019	0.0047	-	5	6	-	-	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.02	-	0.020	<0.01	0.020	-	5	6	-	-	-	-	-
Total ammonia	<0.05	-	0.32	0.019	0.40	-	3	6	-	-	-	-	-
Total Kjeldahl nitrogen	0.75	0.81	1.2	0.55	1.3	0.26	0	6	-	-	-	-	-
Total nitrogen (calculated)	0.76	0.81	1.2	0.55	1.3	0.26	0	6	-	-	-	-	-
Total phosphorus	0.027	0.023	0.034	0.0081	0.035	0.011	0	6	-	-	-	-	-
Dissolved phosphorus	0.012	0.013	0.023	0.0040	0.024	0.0080	0	6	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	<2.0	<2.0	<2.0	-	6	6	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	6	6	-	-	-	-	-
Phenol[e]	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-
Total phenolics[f]	<0.002	-	**0.0037**[W]	<0.002	**0.0038**[W]	-	3	5	-	-	40	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	6	6	-	-	-	-	-
Total Metals													
Aluminum	21	56	152	4.1	162	68	0	6	-	-	-	-	-
Antimony	0.036	-	0.044	<0.02	<0.05	-	3	6	-	-	-	-	-
Arsenic	0.75	0.69	1.0	0.30	1.0	0.33	0	6	-	-	-	-	-
Barium	26	26	33	18	34	6.8	0	6	-	-	-	-	-
Beryllium	<0.01	-	0.019	<0.01	0.021	-	4	6	-	-	-	-	-
Boron	45	68	135	35	140	49	1	6	-	-	-	-	-
Cadmium	<0.005	-	0.012	<0.005	0.012	-	5	6	-	-	-	-	-
Chromium	0.14	-	0.30	<0.1	<0.5	-	4	6	-	-	-	-	-
Cobalt	0.21	0.20	0.42	0.028	0.46	0.16	0	6	-	-	-	-	-
Copper	0.45	0.41	0.76	<0.05	0.79	0.32	1	6	-	-	-	-	-
Iron	**782**[S]	**711**[S]	**1,273**[S]	87	**1,280**[S]	535	0	6	-	-	-	-	67
Lead	0.063	0.12	0.32	0.024	0.39	0.14	0	6	-	-	-	-	-
Lithium	6.6	7.2	11	2.9	11	3.4	0	6	-	-	-	-	-
Manganese	46	47	**61**[S]	33	**64**[S]	10	0	6	-	-	-	-	33
Mercury	0.0015	0.0016	0.0022	0.00098	0.0023	0.00053	0	6	-	-	-	-	-
Methyl mercury	0.00016	-	0.00021	<0.00008	0.00021	-	2	6	-	-	-	-	-
Molybdenum	0.22	0.26	0.54	0.056	0.58	0.20	0	6	-	-	-	-	-
Nickel	1.0	0.86	1.4	0.14	1.4	0.59	0	6	-	-	-	-	-
Selenium	0.060	0.062	0.11	<0.04	0.12	0.034	1	6	-	-	-	-	-
Silver	<0.005	-	<0.01	<0.005	<0.01	-	6	6	-	-	-	-	-
Strontium	78	83	114	61	119	23	0	6	-	-	-	-	-
Thallium	0.0020	-	0.0045	<0.002	0.0050	-	3	6	-	-	-	-	-
Titanium	<2.0	-	3.5	<0.5	<5.0	-	5	6	-	-	-	-	-
Uranium	0.092	0.12	0.28	0.013	0.30	0.12	0	6	-	-	-	-	-
Vanadium	0.48	0.46	0.72	0.21	0.78	0.20	0	6	-	-	-	-	-
Zinc	1.8	1.4	3.1	0.31	3.5	1.3	1	6	-	-	-	-	-
Dissolved Metals													
Aluminum	8.7	8.4	15	1.2	16	6.0	0	6	-	-	-	-	-
Antimony	0.028	-	0.038	<0.02	0.038	-	2	6	-	-	-	-	-
Arsenic	0.66	0.63	0.93	0.28	0.95	0.29	0	6	-	-	-	-	-
Barium	25	25	35	16	35	7.6	0	6	-	-	-	-	-
Beryllium	<0.01	-	0.010	<0.01	0.010	-	5	6	-	-	-	-	-
Boron	49	80	182	20	200	70	0	6	-	-	-	-	-
Cadmium	<0.005	-	0.0058	<0.005	0.0060	-	4	6	-	-	-	-	-
Chromium	<0.1	-	0.10	<0.1	0.10	-	5	6	-	-	-	-	-
Cobalt	0.11	0.12	0.24	0.016	0.25	0.098	0	6	-	-	-	-	-
Copper	0.31	0.33	0.69	0.069	0.77	0.26	0	6	-	-	-	-	-
Iron	**500**[C]	**489**[C]	**968**[C]	8.8	**984**[C]	433	0	6	-	67	-	-	-
Lead	0.012	-	0.056	<0.005	0.063	-	2	6	-	-	-	-	-
Lithium	7.0	8.4	15	3.8	16	4.7	0	6	-	-	-	-	-
Manganese	3.0	12	36	0.16	38	17	0	6	-	-	-	-	-
Mercury	0.0012	0.0011	0.0017	<0.00011	0.0018	0.00060	1	6	-	-	-	-	-
Molybdenum	0.25	0.30	0.59	0.060	0.59	0.24	0	6	-	-	-	-	-
Nickel	1.0	0.86	1.4	0.19	1.4	0.54	0	6	-	-	-	-	-
Selenium	0.060	-	0.080	<0.04	0.082	-	2	6	-	-	-	-	-
Silver	<0.005	-	0.0070	<0.005	0.0070	-	5	6	-	-	-	-	-
Strontium	79	92	138	61	140	35	0	6	-	-	-	-	-
Thallium	0.0020	-	0.0023	<0.002	0.0023	-	3	6	-	-	-	-	-
Titanium	0.63	-	1.2	<0.5	1.2	-	3	6	-	-	-	-	-
Uranium	0.079	0.14	0.35	0.010	0.36	0.16	0	6	-	-	-	-	-
Vanadium	0.31	0.31	0.47	<0.2	0.47	0.15	1	6	-	-	-	-	-
Zinc	0.24	0.43	1.0	0.14	1.1	0.39	0	6	-	-	-	-	-

Table V-4: Operational Phase Seasonal Water Quality Data from the Muskeg Creek Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
										A	C	W	D	S
Field Measured														
pH	-	7.7	7.6	8.0	7.0	8.0	0.48	0	4	-	-	-	-	-
Specific conductivity	µS/cm	216	219	247	193	250	27	0	4	-	-	-	-	-
Temperature	°C	6.9	6.7	13	0	13	5.7	0	4	-	-	-	-	-
Dissolved oxygen	mg/L	13	17	29	9.5	32	10	0	4	-	-	-	-	-
Conventional Parameters														
pH	-	8.1	8.2	8.5	7.9	8.5	0.17	0	16	-	-	-	-	-
Specific conductivity	µS/cm	240	271	455	176	535	101	0	16	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	98	119	194	77	201	43	0	16	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	118	138	245	87	284	57	0	16	-	-	-	-	-
Total dissolved solids	mg/L	194	206	317	145	359	63	0	16	-	-	-	-	-
Total suspended solids	mg/L	<3.0	-	36	<1.0	122	-	8	16	-	-	-	-	-
Total organic carbon	mg/L	25	24	32	6.5	33	6.2	0	16	-	-	-	-	-
Dissolved organic carbon	mg/L	24	24	31	6.3	32	6.1	0	16	-	-	-	-	-
Colour	TCU	**86**(S)	**82**(S)	**157**(S)	**20**(S)	**159**(S)	49	0	13	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	140	166	292	106	329	65	0	16	-	-	-	-	-
Calcium	mg/L	26	31	52	20	56	12	0	16	-	-	-	-	-
Carbonate	mg/L	<5.0	-	6.8	<0.5	8.5	-	12	16	-	-	-	-	-
Chloride	mg/L	1.4	1.8	4.5	0.53	4.6	1.3	2	16	-	-	-	-	-
Magnesium	mg/L	8.6	10	17	6.9	18	3.5	0	16	-	-	-	-	-
Potassium	mg/L	0.89	0.88	1.3	0.36	1.5	0.28	0	16	-	-	-	-	-
Sodium	mg/L	12	15	25	6.0	40	7.8	0	16	-	-	-	-	-
Sulphate	mg/L	2.0	-	8.5	<1.0	12	-	4	16	-	-	-	-	-
Sulphide	mg/L	0.0043	0.0047	0.0095	<0.0019	**0.015**(C)	0.0035	3	16	-	19	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.071	-	0.071	<0.014	0.071	-	10	16	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	0.050	<0.015	0.050	-	9	16	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.92	0.87	1.3	0.50	1.3	0.28	0	16	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.94	0.89	1.4	0.50	1.4	0.29	0	16	-	-	-	-	-
Total phosphorus	mg-P/L	0.029	0.035	0.069	0.012	0.12	0.026	0	16	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.015	0.016	0.035	0.0016	0.037	0.011	0	16	-	-	-	-	-
Biochemical oxygen demand	mg/L	2.0	-	2.3	<2.0	2.6	-	6	16	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	0.52	-	1.2	<0.02	1.2	-	5	16	-	-	-	-	-
Phenol(e)	mg/L	**0.0069**(C, W)	-	**0.0075**(C, W)	<0.002	**0.0076**(C, W)	-	1	3	-	67	67	-	-
Total phenolics(f)	mg/L	**0.0060**(C, W)	**0.0061**(C, W)	**0.010**(C, W)	<0.002	**0.010**(C, W)	0.0030	1	13	-	77	92	-	-
Total recoverable hydrocarbons	mg/L	<1.0	-	<2.0	<1.0	<2.0	-	10	10	-	-	-	-	-
Total Metals														
Aluminum	µg/L	41	224	1,303	7.3	2,000	540	0	16	-	-	-	-	-
Antimony	µg/L	<0.05	-	0.050	0.018	0.050	-	5	16	-	-	-	-	-
Arsenic	µg/L	0.51	0.60	1.2	0.28	1.3	0.32	0	16	-	-	-	-	-
Barium	µg/L	22	28	54	13	64	15	0	16	-	-	-	-	-
Beryllium	µg/L	<0.1	-	0.10	<0.008	0.11	-	6	16	-	-	-	-	-
Boron	µg/L	51	66	125	40	230	46	0	16	-	-	-	-	-
Cadmium	µg/L	0.010	-	<0.1	<0.002	<0.1	-	8	16	-	-	-	-	-
Chromium	µg/L	<0.3	-	**1.5**(C)	<0.1	**3.2**(C)	-	6	16	-	6.0	-	-	-
Cobalt	µg/L	0.10	0.18	0.57	0.011	**1.2**(C)	0.29	3	16	-	6.0	-	-	-
Copper	µg/L	0.30	0.43	1.5	0.098	1.7	0.47	1	16	-	-	-	-	-
Iron	µg/L	**515**(S)	**720**(S)	**1,845**(S)	60	**3,000**(S)	766	0	16	-	-	-	-	63
Lead	µg/L	<0.1	0.16	0.54	0.014	1.4	0.32	3	16	-	-	-	-	-
Lithium	µg/L	7.6	9.2	18	6.0	24	4.7	0	16	-	-	-	-	-
Manganese	µg/L	37	44	**90**(S)	18	**95**(S)	24	0	16	-	-	-	-	31
Mercury	µg/L	0.0011	0.0016	0.0038	0.00071	**0.0081**(C)	0.0018	0	16	-	6.0	-	-	-
Methyl mercury	µg/L	0.000090	-	0.00014	<0.00008	0.00015	-	2	4	-	-	-	-	-
Molybdenum	µg/L	0.12	0.17	0.44	0.032	0.47	0.14	3	16	-	-	-	-	-
Nickel	µg/L	0.24	0.52	1.9	0.024	2.3	0.66	3	16	-	-	-	-	-
Selenium	µg/L	<0.3	-	0.30	<0.04	0.30	-	5	16	-	-	-	-	-
Silver	µg/L	0.010	-	0.054	<0.002	0.073	-	7	16	-	-	-	-	-
Strontium	µg/L	80	98	175	60	190	40	0	16	-	-	-	-	-
Thallium	µg/L	<0.1	-	0.10	<0.0009	0.10	-	6	16	-	-	-	-	-
Titanium	µg/L	1.7	4.3	19	<0.5	32	8.2	2	16	-	-	-	-	-
Uranium	µg/L	0.10	0.14	0.39	0.0040	0.53	0.13	1	16	-	-	-	-	-
Vanadium	µg/L	0.29	0.70	2.8	0.16	5.4	1.3	1	16	-	-	-	-	-
Zinc	µg/L	1.2	1.9	5.5	0.60	7.5	1.9	2	16	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	6.4	9.4	31	0.81	**51**(C)	13	0	16	-	6.0	-	-	-
Antimony	µg/L	<0.05	-	0.050	0.018	0.050	-	4	16	-	-	-	-	-
Arsenic	µg/L	0.43	0.49	0.82	0.27	0.93	0.20	0	16	-	-	-	-	-
Barium	µg/L	20	24	45	10	60	13	0	16	-	-	-	-	-
Beryllium	µg/L	<0.1	-	0.10	<0.009	0.10	-	10	16	-	-	-	-	-
Boron	µg/L	50	62	122	30	220	44	0	16	-	-	-	-	-
Cadmium	µg/L	0.010	-	<0.1	<0.002	<0.1	-	10	16	-	-	-	-	-
Chromium	µg/L	<0.3	-	0.41	<0.1	0.50	-	8	16	-	-	-	-	-
Cobalt	µg/L	0.10	0.099	0.22	0.011	0.24	0.068	3	16	-	-	-	-	-
Copper	µg/L	0.26	0.28	0.62	0.051	0.78	0.20	0	16	-	-	-	-	-
Iron	µg/L	256	**327**(C)	**835**(C)	3.8	**883**(C)	313	1	16	-	50	-	-	-
Lead	µg/L	<0.1	-	0.10	<0.005	0.10	-	4	16	-	-	-	-	-
Lithium	µg/L	7.3	8.8	17	4.0	24	4.8	0	16	-	-	-	-	-
Manganese	µg/L	9.7	13	40	0.12	71	18	0	16	-	-	-	-	-
Mercury	µg/L	<0.05	-	0.050	0.00026	0.050	-	6	16	-	-	-	-	-
Molybdenum	µg/L	0.11	0.16	0.43	0.018	0.44	0.14	3	16	-	-	-	-	-
Nickel	µg/L	0.20	0.35	1.0	0.023	1.6	0.41	3	16	-	-	-	-	-
Selenium	µg/L	<0.3	-	0.30	<0.04	0.30	-	6	16	-	-	-	-	-
Silver	µg/L	<0.01	-	0.010	<0.001	0.010	-	8	16	-	-	-	-	-
Strontium	µg/L	77	90	145	60	160	33	0	16	-	-	-	-	-
Thallium	µg/L	<0.1	-	0.10	0.00080	0.10	-	6	16	-	-	-	-	-
Titanium	µg/L	0.88	1.2	3.6	0.20	3.7	1.0	2	16	-	-	-	-	-
Uranium	µg/L	0.10	0.13	0.38	0.0040	0.49	0.13	1	16	-	-	-	-	-
Vanadium	µg/L	0.20	0.24	0.50	0.11	0.60	0.13	2	16	-	-	-	-	-
Zinc	µg/L	0.70	1.0	2.6	0.21	3.4	0.88	0	16	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (53 to 246 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (4.1 to 10.4). The guideline is calculated based on the individual pH for each sample.
(d) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.019 mg-N/L) is presented and was calculated based on the combination of field pH (10.4) and water temperature (10.7°C). Guidelines calculated with temperature and pH values falling outside the defined range (i.e., pH 6.0 to 10.0 and temperature 0°C to 30°C) should be used with caution, as the WQG does not necessarily accurately reflect toxic effects at the low and high pH and temperature extremes. The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(e) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(f) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(g) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline, below the recommended DO guideline or outside the recommended pH range.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.
- = not applicable, no guideline, or no data available; μS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; μg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO =

Table V-5: Baseline Phase Seasonal Water Quality Data from the Muskeg River Watershed Compared to Guidelines, 2007 to 2010

Guidelines (GOA (2018) Guidelines for the Protection of: Aquatic Life – Acute, Chronic; Wildlife Health (Livestock); Health Canada (2017): Drinking Water MAC, Drinking Water AO)

Parameter	Unit	Aquatic Life Acute	Aquatic Life Chronic	Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO
Field Measured						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11
Specific conductivity	µS/cm	-	-	-	-	-
Temperature	°C	-	-	-	-	15
Dissolved oxygen	mg/L	5.0	6.5	-	-	-
Conventional Parameters						
pH	-	-	6.5 to 9.0	-	-	7.0 to 11
Specific conductivity	µS/cm	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500
Total suspended solids	mg/L	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-
Colour	TCU	-	-	-	-	15
Major Ions						
Bicarbonate	mg/L	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-
Carbonate	mg/L	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250
Magnesium	mg/L	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200
Sulphate	mg/L	-	309 to 429[b, c]	1,000	-	500
Sulphide	mg/L	-	0.0023 to 0.023[d]	-	-	0.050
Nutrients and Biological Indicators						
Nitrate + nitrite	mg-N/L	-	-	100	-	-
Total ammonia	mg-N/L	-	0.40[e]	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-
General Organics						
Naphthenic acids	mg/L	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-
Total Metals						
Aluminum	µg/L	-	-	5,000	-	-
Antimony	µg/L	-	-	-	6.0	-
Arsenic	µg/L	-	5.0	25	10	-
Barium	µg/L	-	-	-	1,000	-
Beryllium	µg/L	-	-	100	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-
Cadmium	µg/L	2.0 to 6.6[b]	0.15 to 0.37[b]	80	5.0	-
Chromium	µg/L	-	1.0[h]	50	50[h]	-
Cobalt	µg/L	-	1.0 - 1.6[b]	1,000	-	-
Copper	µg/L	16 to 48[b]	7.0[b]	500	-	1,000
Iron	µg/L	-	-	-	-	300
Lead	µg/L	-	3.1 to 7.0[b]	100	10	-
Lithium	µg/L	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50
Mercury	µg/L	0.013	0.0050	3.0	1.0	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-
Molybdenum	µg/L	-	73	500	-	-
Nickel	µg/L	457 to 1,219[b]	51 to 135[b]	1,000	-	-
Selenium	µg/L	-	2.0	50	50	-
Silver	µg/L	-	0.25	-	-	-
Strontium	µg/L	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-
Titanium	µg/L	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-
Vanadium	µg/L	-	-	100	-	-
Zinc	µg/L	-	30	50,000	-	5,000
Dissolved Metals						
Aluminum	µg/L	100[d]	50[d]	-	-	-
Antimony	µg/L	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-
Barium	µg/L	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-
Boron	µg/L	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-
Copper	µg/L	-	-	-	-	-
Iron	µg/L	-	300	-	-	-
Lead	µg/L	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-
Silver	µg/L	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-

Seasonal Summary – Winter

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	**7.0[S]**	7.1	7.7	**6.6[S]**	7.8	0.36	0	12	-	-	-	-	50
Specific conductivity	534	510	576	367	587	70	0	12	-	-	-	-	-
Temperature	0.15	0.15	0.45	-0.1	0.50	0.19	0	12	-	-	-	-	-
Dissolved oxygen	**1.6[A, C]**	**2.0[A, C]**	**4.9[A, C]**	**0.20[A, C]**	**5.9[C]**	1.7	0	12	92	100	-	-	-
Conventional Parameters													
pH	7.1	7.2	7.8	7.0	7.9	0.29	0	13	-	-	-	-	-
Specific conductivity	557	518	585	359	589	78	0	13	-	-	-	-	-
Hardness, as $CaCO_3$	272	257	298	186	309	40	0	13	-	-	-	-	-
Total alkalinity, as $CaCO_3$	314	289	332	194	339	47	0	13	-	-	-	-	-
Total dissolved solids	299	277	315	191	316	44	0	13	-	-	-	-	-
Total suspended solids	9.0	7.4	11	<1.0	12	3.6	1	13	-	-	-	-	-
Total organic carbon	10	-	10	-	-	-	0	1	-	-	-	-	-
Dissolved organic carbon	17	16	18	10	19	2.2	0	13	-	-	-	-	-
Colour	**49[S]**	**46[S]**	**62[S]**	**29[S]**	**70[S]**	12	0	11	-	-	-	-	100
Major Ions													
Bicarbonate	383	352	404	237	413	57	0	13	-	-	-	-	-
Calcium	67	62	69	42	69	9.4	0	11	-	-	-	-	-
Carbonate	<0.5	-	<0.5	-	-	-	1	1	-	-	-	-	-
Chloride	2.0	2.4	3.4	1.0	4.0	0.77	0	13	-	-	-	-	-
Magnesium	28	-	28	-	-	-	0	1	-	-	-	-	-
Potassium	1.1	1.0	1.7	<0.1	1.8	0.56	2	13	-	-	-	-	-
Sodium	8.0	8.2	10	3.0	11	2.0	0	13	-	-	-	-	-
Sulphate	<3.0	-	6.0	<1.0	6.0	-	12	13	-	-	-	-	-
Sulphide	0.0020	0.0024	0.0040	0.0010	0.0050	0.0010	0	11	-	9.0	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	0.0070	-	0.029	<0.005	0.036	-	5	13	-	-	-	-	-
Total ammonia	0.30	-	0.30	-	-	-	0	1	-	-	-	-	-
Total Kjeldahl nitrogen	1.3	1.1	1.4	0.63	1.4	0.29	0	13	-	-	-	-	-
Total nitrogen (calculated)	1.3	1.1	1.4	0.63	1.4	0.29	0	13	-	-	-	-	-
Total phosphorus	0.070	0.070	0.12	0.030	0.13	0.030	0	13	-	-	-	-	-
Dissolved phosphorus	0.017	0.015	0.025	0.0050	0.027	0.0065	0	13	-	-	-	-	-
Biochemical oxygen demand	2.4	2.4	3.8	1.6	4.5	0.87	1	13	-	-	-	-	-
General Organics													
Naphthenic acids	<0.1	-	<1.0	<0.1	<1.0	-	7	7	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0040[W]**	-	**0.0040[W]**	-	-	-	0	1	-	-	100	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	-	-	-	1	1	-	-	-	-	-
Total Metals													
Aluminum	20	17	28	10	40	8.5	0	13	-	-	-	-	-
Antimony	0.010	0.014	0.024	0.010	0.030	0.0065	1	13	-	-	-	-	-
Arsenic	0.20	0.24	0.30	0.20	0.30	0.051	0	13	-	-	-	-	-
Barium	66	70	102	28	103	26	0	13	-	-	-	-	-
Beryllium	0.0060	0.0061	0.012	<0.003	0.012	0.0035	3	13	-	-	-	-	-
Boron	42	37	51	22	51	9.8	1	13	-	-	-	-	-
Cadmium	0.0070	0.016	0.042	<0.002	0.043	0.017	2	13	-	-	-	-	-
Chromium	0.28	0.26	0.45	<0.04	0.46	0.15	3	13	-	-	-	-	-
Cobalt	0.23	0.24	0.34	0.080	0.35	0.076	0	13	-	-	-	-	-
Copper	0.26	0.31	0.60	<0.05	0.64	0.20	1	13	-	-	-	-	-
Iron	**3,000[S]**	**3,000[S]**	**4,000[S]**	**1,000[S]**	**4,000[S]**	1,155	0	13	-	-	-	-	100
Lead	0.040	0.067	0.21	<0.001	0.22	0.075	1	13	-	-	-	-	-
Lithium	10	9.0	11	5.0	12	2.1	0	13	-	-	-	-	-
Manganese	**1,000[S]**	**678[S]**	**1,000[S]**	**120[S]**	**1,000[S]**	375	0	13	-	-	-	-	100
Mercury	0.00040	-	0.0011	#######	0.0016	-	3	11	-	-	-	-	-
Methyl mercury	<0.00003	-	<0.00003	-	-	-	1	1	-	-	-	-	-
Molybdenum	0.040	0.061	0.15	0.030	0.19	0.047	0	13	-	-	-	-	-
Nickel	<0.005	-	1.5	<0.005	1.6	-	8	13	-	-	-	-	-
Selenium	0.13	0.14	0.27	<0.04	0.27	0.082	3	13	-	-	-	-	-
Silver	0.0040	-	0.028	<0.0005	0.041	-	5	13	-	-	-	-	-
Strontium	180	175	224	90	230	46	0	13	-	-	-	-	-
Thallium	0.0014	-	0.0041	<0.0003	0.0064	-	5	13	-	-	-	-	-
Titanium	2.7	2.6	3.5	<0.5	3.6	0.82	1	13	-	-	-	-	-
Uranium	0.040	0.058	0.11	0.020	0.13	0.035	0	13	-	-	-	-	-
Vanadium	0.40	0.46	0.78	<0.2	0.90	0.22	1	13	-	-	-	-	-
Zinc	1.2	1.9	5.2	0.60	7.4	1.9	0	13	-	-	-	-	-
Dissolved Metals													
Aluminum	3.0	2.5	3.5	1.0	4.0	1.0	0	11	-	-	-	-	-
Antimony	0.010	0.014	0.025	0.010	0.030	0.0067	1	11	-	-	-	-	-
Arsenic	0.20	0.17	0.20	0.10	0.20	0.047	0	11	-	-	-	-	-
Barium	50	56	90	30	90	22	0	11	-	-	-	-	-
Beryllium	0.0050	-	0.012	<0.003	0.012	-	5	11	-	-	-	-	-
Boron	40	34	50	20	50	9.7	1	11	-	-	-	-	-
Cadmium	<0.005	0.0078	0.024	<0.002	0.029	0.0087	2	11	-	-	-	-	-
Chromium	0.22	-	0.38	<0.04	0.43	-	3	11	-	-	-	-	-
Cobalt	0.23	0.21	0.29	0.070	0.30	0.073	0	11	-	-	-	-	-
Copper	0.30	0.24	0.35	<0.05	0.40	0.11	1	11	-	-	-	-	-
Iron	**370[C]**	**433[C]**	**1,000[C]**	100	**1,000[C]**	296	0	11	-	64	-	-	-
Lead	0.0080	0.0081	0.018	<0.001	0.021	0.0060	1	11	-	-	-	-	-
Lithium	9.0	8.5	11	5.0	11	2.0	0	11	-	-	-	-	-
Manganese	430	439	720	110	740	210	0	11	-	-	-	-	-
Mercury	<0.0006	-	<0.0006	-	-	-	1	1	-	-	-	-	-
Molybdenum	0.030	0.030	0.055	0.010	0.060	0.015	1	11	-	-	-	-	-
Nickel	<0.005	-	1.4	<0.005	1.5	-	8	11	-	-	-	-	-
Selenium	<0.1	-	0.25	<0.04	0.26	-	4	11	-	-	-	-	-
Silver	<0.0005	-	0.0010	<0.0005	<0.005	-	8	11	-	-	-	-	-
Strontium	170	158	210	90	210	42	0	11	-	-	-	-	-
Thallium	0.0010	-	0.0045	<0.0003	0.0060	-	4	11	-	-	-	-	-
Titanium	1.9	1.8	2.2	<0.5	2.2	0.54	1	11	-	-	-	-	-
Uranium	0.040	0.062	0.12	0.030	0.14	0.035	0	11	-	-	-	-	-
Vanadium	0.19	0.17	0.32	0.020	0.33	0.093	1	11	-	-	-	-	-
Zinc	0.90	1.2	2.5	0.20	2.7	0.79	0	11	-	-	-	-	-

Seasonal Summary – Spring

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.2	7.2	7.5	7.1	7.6	0.21	0	5	-	-	-	-	-
Specific conductivity	222	209	227	184	227	22	0	5	-	-	-	-	-
Temperature	9.4	6.2	11	0.10	11	5.5	0	5	-	-	-	-	-
Dissolved oxygen	7.2	7.4	8.4	6.7	8.6	0.82	0	4	-	-	-	-	-
Conventional Parameters													
pH	7.5	7.5	7.7	**6.9[S]**	7.7	0.30	0	6	-	-	-	-	17
Specific conductivity	187	194	222	170	225	21	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	99	102	111	97	111	6.4	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	96	100	117	89	117	13	0	6	-	-	-	-	-
Total dissolved solids	119	115	121	102	121	8.3	0	6	-	-	-	-	-
Total suspended solids	4.0	5.4	11	2.0	12	4.0	0	5	-	-	-	-	-
Total organic carbon	17	17	17	17	17	0	0	2	-	-	-	-	-
Dissolved organic carbon	17	17	20	14	20	2.6	0	6	-	-	-	-	-
Colour	**73[S]**	**66[S]**	**88[S]**	**44[S]**	**90[S]**	21	0	5	-	-	-	-	100
Major Ions													
Bicarbonate	116	123	142	110	143	15	0	6	-	-	-	-	-
Calcium	24	25	28	23	29	2.5	0	5	-	-	-	-	-
Carbonate	<0.5	-	<0.5	<0.5	<0.5	-	2	2	-	-	-	-	-
Chloride	1.0	0.92	1.0	<1.0	1.0	0.20	1	6	-	-	-	-	-
Magnesium	8.9	8.9	8.9	8.9	8.9	0	0	2	-	-	-	-	-
Potassium	1.4	1.4	2.0	0.90	2.2	0.42	0	6	-	-	-	-	-
Sodium	4.0	4.2	5.5	3.0	6.0	0.98	0	6	-	-	-	-	-
Sulphate	4.0	-	8.0	<1.0	9.0	-	3	6	-	-	-	-	-
Sulphide	0.0020	0.0032	0.0060	0.0010	0.0060	0.0026	0	5	-	-	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	0.0050	-	0.036	<0.003	0.046	-	3	6	-	-	-	-	-
Total ammonia	<0.05	-	<0.05	<0.05	<0.05	-	2	2	-	-	-	-	-
Total Kjeldahl nitrogen	0.65	0.68	0.85	0.59	0.91	0.12	0	6	-	-	-	-	-
Total nitrogen (calculated)	0.66	0.69	0.88	0.59	0.96	0.14	0	6	-	-	-	-	-
Total phosphorus	0.025	0.040	0.098	0.020	0.12	0.039	0	6	-	-	-	-	-
Dissolved phosphorus	0.015	0.018	0.032	0.0090	0.035	0.0097	0	6	-	-	-	-	-
Biochemical oxygen demand	<4.0	-	<4.0	2.1	<4.0	-	2	3	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<0.1	<1.0	-	4	4	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	<0.002	-	<0.002	<0.002	<0.002	-	2	2	-	-	-	-	-
Total recoverable hydrocarbons	-	-	-	-	-	-	0	0	-	-	-	-	-
Total Metals													
Aluminum	50	53	78	30	80	20	0	6	-	-	-	-	-
Antimony	0.020	0.017	0.020	0.010	0.020	0.0052	1	6	-	-	-	-	-
Arsenic	0.21	0.23	0.30	0.18	0.30	0.054	0	6	-	-	-	-	-
Barium	22	24	36	15	38	8.8	0	6	-	-	-	-	-
Beryllium	0.0070	-	<0.01	<0.003	<0.01	-	3	6	-	-	-	-	-
Boron	26	-	<50	20	<50	-	2	6	-	-	-	-	-
Cadmium	0.0040	0.040	0.17	<0.002	**0.22[C]**	0.088	1	6	-	17	-	-	-
Chromium	<0.1	-	0.17	<0.04	0.17	-	3	6	-	-	-	-	-
Cobalt	0.075	0.082	0.13	0.040	0.13	0.041	0	6	-	-	-	-	-
Copper	0.25	-	0.40	<0.05	0.40	-	2	6	-	-	-	-	-
Iron	**700[S]**	**1,467[S]**	**3,750[S]**	200	**4,000[S]**	1,633	0	6	-	-	-	-	67
Lead	0.045	0.055	0.11	0.030	0.12	0.034	0	6	-	-	-	-	-
Lithium	3.5	3.8	5.5	3.0	6.0	1.2	0	6	-	-	-	-	-
Manganese	15	45	**145[S]**	10	**180[S]**	67	0	6	-	-	-	-	17
Mercury	0.0013	0.0014	0.0023	0.00070	0.0025	0.00069	0	6	-	-	-	-	-
Methyl mercury	<0.00003	-	<0.00003	<0.00003	<0.00003	-	2	2	-	-	-	-	-
Molybdenum	0.13	0.15	0.20	0.10	0.21	0.039	0	6	-	-	-	-	-
Nickel	0.15	0.29	0.63	0.10	0.64	0.25	0	6	-	-	-	-	-
Selenium	<0.1	-	<0.1	<0.04	<0.1	-	6	6	-	-	-	-	-
Silver	0.0040	-	0.046	0.0030	0.046	-	2	6	-	-	-	-	-
Strontium	55	55	70	40	70	14	0	6	-	-	-	-	-
Thallium	0.0020	0.0019	0.0027	0.0012	0.0028	0.00069	1	6	-	-	-	-	-
Titanium	1.3	1.5	2.8	0.70	3.1	0.85	0	6	-	-	-	-	-
Uranium	0.025	0.027	0.048	0.010	0.050	0.016	0	6	-	-	-	-	-
Vanadium	0.20	-	0.38	<0.2	0.40	-	2	6	-	-	-	-	-
Zinc	2.3	3.1	7.4	0.60	8.4	2.9	0	6	-	-	-	-	-
Dissolved Metals													
Aluminum	4.0	13	29	3.0	30	13	0	5	-	-	-	-	-
Antimony	0.020	0.020	0.028	0.010	0.030	0.0071	0	5	-	-	-	-	-
Arsenic	0.20	0.20	0.20	0.20	0.20	0	0	5	-	-	-	-	-
Barium	20	22	28	20	30	4.5	0	5	-	-	-	-	-
Beryllium	<0.003	-	<0.01	<0.003	<0.01	-	5	5	-	-	-	-	-
Boron	20	-	<50	20	<50	-	2	5	-	-	-	-	-
Cadmium	<0.005	-	0.066	<0.002	0.080	-	2	5	-	-	-	-	-
Chromium	<0.1	-	0.15	<0.04	0.15	-	3	5	-	-	-	-	-
Cobalt	0.070	0.066	0.096	0.040	0.10	0.026	0	5	-	-	-	-	-
Copper	0.40	0.46	0.60	0.30	0.60	0.13	0	5	-	-	-	-	-
Iron	190	**338[C]**	**848[C]**	100	**1,000[C]**	374	0	5	-	20	-	-	-
Lead	0.024	0.039	0.088	0.0080	0.099	0.036	0	5	-	-	-	-	-
Lithium	4.0	3.6	4.0	3.0	4.0	0.55	0	5	-	-	-	-	-
Manganese	7.0	39	132	4.0	160	68	0	5	-	-	-	-	-
Mercury	<0.0006	-	<0.0006	<0.0006	<0.0006	-	2	2	-	-	-	-	-
Molybdenum	0.12	0.14	0.19	0.11	0.20	0.039	0	5	-	-	-	-	-
Nickel	0.14	0.28	0.58	0.060	0.60	0.26	0	5	-	-	-	-	-
Selenium	<0.04	-	<0.1	<0.04	<0.1	-	5	5	-	-	-	-	-
Silver	<0.0005	-	<0.005	<0.0005	<0.005	-	5	5	-	-	-	-	-
Strontium	50	50	60	40	60	10	0	5	-	-	-	-	-
Thallium	<0.002	-	0.0030	0.0010	0.0030	-	2	5	-	-	-	-	-
Titanium	0.60	-	1.0	<0.5	1.1	-	2	5	-	-	-	-	-
Uranium	0.030	0.026	0.040	0.010	0.040	0.015	0	5	-	-	-	-	-
Vanadium	0.15	-	<0.2	0.080	<0.2	-	2	5	-	-	-	-	-
Zinc	1.2	3.1	6.5	0.60	6.7	2.9	0	5	-	-	-	-	-

Seasonal Summary – Summer

Parameter	Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.3	7.3	7.7	7.0	7.8	0.23	0	9	-	-	-	-	-
Specific conductivity	356	396	609	246	681	129	0	9	-	-	-	-	-
Temperature	**16[S]**	**16[S]**	**19[S]**	14	**19[S]**	1.8	0	9	-	-	-	-	78
Dissolved oxygen	**5.5[C]**	**5.4[C]**	7.3	**3.7[A, C]**	7.8	1.3	0	9	33	78	-	-	-
Conventional Parameters													
pH	7.9	7.8	8.3	7.4	8.4	0.34	0	11	-	-	-	-	-
Specific conductivity	357	345	432	230	455	66	0	11	-	-	-	-	-
Hardness, as $CaCO_3$	174	184	242	131	260	38	0	11	-	-	-	-	-
Total alkalinity, as $CaCO_3$	190	188	250	121	269	42	0	11	-	-	-	-	-
Total dissolved solids	190	205	263	166	266	36	0	11	-	-	-	-	-
Total suspended solids	3.0	4.3	14	1.0	21	6.0	1	10	-	-	-	-	-
Total organic carbon	24	24	27	20	28	3.3	0	4	-	-	-	-	-
Dissolved organic carbon	24	24	28	19	28	2.6	0	11	-	-	-	-	-
Colour	**97[S]**	**93[S]**	**125[S]**	**61[S]**	**128[S]**	23	0	10	-	-	-	-	100
Major Ions													
Bicarbonate	238	230	300	148	328	51	0	11	-	-	-	-	-
Calcium	44	44	57	32	59	8.9	0	10	-	-	-	-	-
Carbonate	4.0	-	<5.0	<0.5	<5.0	-	4	5	-	-	-	-	-
Chloride	1.0	1.3	2.0	<1.0	2.0	0.61	2	11	-	-	-	-	-
Magnesium	16	16	20	12	20	4.6	0	4	-	-	-	-	-
Potassium	0.50	0.55	0.90	0.30	1.0	0.24	1	11	-	-	-	-	-
Sodium	4.0	4.5	7.0	3.0	8.0	1.5	0	11	-	-	-	-	-
Sulphate	<3.0	-	5.0	<1.0	6.0	-	7	11	-	-	-	-	-
Sulphide	0.0035	**0.0054[C]**	0.012	<0.002	0.012	0.0040	1	10	-	30	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	0.011	-	<0.071	<0.003	<0.071	-	6	11	-	-	-	-	-
Total ammonia	<0.05	-	0.10	<0.05	0.10	-	3	4	-	-	-	-	-
Total Kjeldahl nitrogen	0.91	0.93	1.2	0.71	1.2	0.14	0	11	-	-	-	-	-
Total nitrogen (calculated)	0.91	0.94	1.2	0.71	1.2	0.14	0	11	-	-	-	-	-
Total phosphorus	0.040	0.039	0.055	0.020	0.060	0.013	0	11	-	-	-	-	-
Dissolved phosphorus	0.024	0.023	0.039	0.012	0.042	0.0098	0	11	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	6.1	<2.0	6.1	-	3	4	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	4	4	-	-	-	-	-
Phenol[f]	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	**0.0040[W]**	-	**0.0067[C, W]**	<0.002	**0.0070[C, W]**	-	1	4	-	50	75	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	2	2	-	-	-	-	-
Total Metals													
Aluminum	40	47	100	10	110	35	0	11	-	-	-	-	-
Antimony	0.020	0.054	<0.4	0.010	<0.4	0.073	2	11	-	-	-	-	-
Arsenic	0.40	0.38	0.46	0.30	0.46	0.079	1	11	-	-	-	-	-
Barium	37	45	81	22	90	20	0	11	-	-	-	-	-
Beryllium	0.0060	-	<1.0	<0.003	<1.0	-	6	11	-	-	-	-	-
Boron	27	-	38	<20	<50	-	4	11	-	-	-	-	-
Cadmium	0.0060	0.0067	0.014	<0.002	0.015	0.0048	2	9	-	-	-	-	-
Chromium	0.20	0.29	0.96	0.10	0.96	0.25	2	11	-	-	-	-	-
Cobalt	0.12	0.12	<0.2	0.090	<0.2	0.033	2	11	-	-	-	-	-
Copper	0.29	-	<1.0	<0.05	<1.0	-	3	11	-	-	-	-	-
Iron	**1,000[S]**	**1,018[S]**	**2,000[S]**	300	**2,000[S]**	556	0	11	-	-	-	-	91
Lead	0.050	0.056	0.16	<0.001	0.20	0.058	2	11	-	-	-	-	-
Lithium	<6.0	5.6	8.5	5.0	9.0	1.9	2	11	-	-	-	-	-
Manganese	**70[S]**	**86[S]**	**180[S]**	20	**200[S]**	58	0	11	-	-	-	-	64
Mercury	0.0010	0.0011	0.0018	<0.0006	0.0020	0.00051	2	11	-	-	-	-	-
Methyl mercury	0.000050	-	0.000076	<0.00003	0.000080	-	2	4	-	-	-	-	-
Molybdenum	0.080	0.092	0.14	0.060	0.16	0.030	0	11	-	-	-	-	-
Nickel	0.63	0.60	1.5	<0.005	1.5	0.53	2	11	-	-	-	-	-
Selenium	0.14	-	<0.4	0.050	<0.4	-	3	11	-	-	-	-	-
Silver	<0.005	-	0.21	<0.0005	0.21	-	6	11	-	-	-	-	-
Strontium	110	108	150	60	160	30	0	11	-	-	-	-	-
Thallium	<0.002	-	0.12	<0.0003	0.12	-	5	11	-	-	-	-	-
Titanium	2.1	2.2	<5.0	0.90	<5.0	0.76	2	11	-	-	-	-	-
Uranium	0.050	0.058	0.13	0.030	0.13	0.035	2	11	-	-	-	-	-
Vanadium	0.30	0.38	0.95	<0.2	1.3	0.33	2	11	-	-	-	-	-
Zinc	0.90	3.4	12	0.70	12	4.5	0	11	-	-	-	-	-
Dissolved Metals													
Aluminum	4.0	8.3	27	2.0	30	10	2	10	-	-	-	-	-
Antimony	0.020	0.058	<0.4	0.020	<0.4	0.075	2	10	-	-	-	-	-
Arsenic	<0.4	0.32	0.46	0.20	0.50	0.10	2	10	-	-	-	-	-
Barium	35	37	56	20	60	13	0	10	-	-	-	-	-
Beryllium	0.0050	-	<0.5	<0.003	<0.5	-	8	10	-	-	-	-	-
Boron	20	23	30	<20	<50	6.3	2	10	-	-	-	-	-
Cadmium	0.0050	-	<0.1	<0.002	<0.1	-	4	10	-	-	-	-	-
Chromium	0.15	-	<0.4	<0.1	<0.4	-	3	10	-	-	-	-	-
Cobalt	0.085	0.090	0.16	0.070	0.17	0.039	2	10	-	-	-	-	-
Copper	0.30	0.28	<0.6	0.10	<0.6	0.10	2	10	-	-	-	-	-
Iron	**375[C]**	**501[C]**	**1,000[C]**	120	**1,000[C]**	358	0	10	-	60	-	-	-
Lead	0.035	0.032	<0.1	0.0060	<0.1	0.019	2	10	-	-	-	-	-
Lithium	5.0	4.9	6.6	3.0	7.0	1.2	0	10	-	-	-	-	-
Manganese	24	39	99	7.0	110	34	0	10	-	-	-	-	-
Mercury	<0.0006	-	0.00060	<0.0006	0.00060	-	3	4	-	-	-	-	-
Molybdenum	0.085	0.079	0.11	0.060	0.11	0.021	1	10	-	-	-	-	-
Nickel	0.36	0.42	0.94	<0.005	0.98	0.34	1	10	-	-	-	-	-
Selenium	0.11	-	<0.4	0.060	<0.4	-	3	10	-	-	-	-	-
Silver	<0.0005	-	<0.005	<0.0005	<0.005	-	8	10	-	-	-	-	-
Strontium	105	101	131	60	140	23	0	10	-	-	-	-	-
Thallium	<0.002	-	<0.05	<0.0003	<0.05	-	5	10	-	-	-	-	-
Titanium	1.0	1.1	1.9	<0.5	2.0	0.60	2	10	-	-	-	-	-
Uranium	0.050	0.052	0.11	0.020	0.12	0.033	2	10	-	-	-	-	-
Vanadium	0.17	0.16	0.22	0.12	0.23	0.046	2	10	-	-	-	-	-
Zinc	0.90	2.4	9.2	0.20	13	3.9	1	10	-	-	-	-	-

Table V-5: Baseline Phase Seasonal Water Quality Data from the Muskeg River Watershed Compared to Guidelines, 2007 to 2010

Parameter	Unit	Seasonal Summary – Fall								% Above Guideline				
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	A	C	W	D	S
Field Measured														
pH	-	7.4	7.4	8.0	**6.8**[(S)]	8.2	0.46	0	6	-	-	-	-	17
Specific conductivity	µS/cm	328	338	405	289	419	46	0	7	-	-	-	-	-
Temperature	°C	5.2	5.2	8.8	1.8	8.9	3.3	0	7	-	-	-	-	-
Dissolved oxygen	mg/L	6.6	6.8	9.9	**3.2**[(A, C)]	10	2.9	0	7	29	43	-	-	-
Conventional Parameters														
pH	-	8.0	7.9	8.3	7.4	8.3	0.29	0	11	-	-	-	-	-
Specific conductivity	µS/cm	303	311	362	255	377	33	0	11	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	160	161	178	139	182	12	0	11	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	166	167	198	131	207	20	0	11	-	-	-	-	-
Total dissolved solids	mg/L	198	193	218	162	225	20	0	11	-	-	-	-	-
Total suspended solids	mg/L	<3.0	-	9.0	<1.0	15	-	7	11	-	-	-	-	-
Total organic carbon	mg/L	22	23	31	15	32	5.8	0	6	-	-	-	-	-
Dissolved organic carbon	mg/L	21	22	30	13	32	5.4	0	11	-	-	-	-	-
Colour	TCU	**81**[(S)]	**78**[(S)]	**98**[(S)]	**49**[(S)]	**99**[(S)]	18	0	10	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	202	203	241	160	252	24	0	11	-	-	-	-	-
Calcium	mg/L	38	40	48	34	51	5.1	0	10	-	-	-	-	-
Carbonate	mg/L	<5.0	-	<5.0	<0.5	<5.0	-	6	6	-	-	-	-	-
Chloride	mg/L	1.0	1.0	1.5	<1.0	2.0	0.35	1	11	-	-	-	-	-
Magnesium	mg/L	14	15	16	13	16	1.2	0	6	-	-	-	-	-
Potassium	mg/L	0.70	0.85	1.6	<0.5	1.7	0.42	1	11	-	-	-	-	-
Sodium	mg/L	5.0	4.5	6.0	3.0	6.0	1.4	0	11	-	-	-	-	-
Sulphate	mg/L	<3.0	-	5.0	<1.0	5.0	-	6	11	-	-	-	-	-
Sulphide	mg/L	0.0050	0.0055	0.011	0.0020	0.011	0.0032	0	10	-	20	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.02	-	<0.1	<0.005	<0.1	-	8	11	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	<0.05	<0.05	<0.05	-	6	6	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.78	0.94	1.9	0.60	1.9	0.48	0	11	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.79	0.95	1.9	0.60	1.9	0.48	0	11	-	-	-	-	-
Total phosphorus	mg-P/L	0.025	0.027	0.046	0.010	0.050	0.012	0	10	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.017	0.018	0.028	0.0090	0.030	0.0072	0	10	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	<2.0	0.90	<2.0	-	6	7	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	<1.0	-	<1.0	0.050	<1.0	-	4	6	-	-	-	-	-
Phenol[(l)]	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[(u)]	mg/L	**0.0055**[(C, W)]	**0.0092**[(C, W)]	**0.025**[(C, W)]	<0.002	**0.031**[(C, W)]	0.011	1	6	-	50	83	-	-
Total recoverable hydrocarbons	mg/L	<1.0	-	<2.0	<1.0	<2.0	-	6	6	-	-	-	-	-
Total Metals														
Aluminum	µg/L	20	22	40	10	40	13	0	11	-	-	-	-	-
Antimony	µg/L	0.020	-	<0.4	0.010	<0.4	-	3	11	-	-	-	-	-
Arsenic	µg/L	0.30	0.28	0.50	0.10	0.50	0.11	1	11	-	-	-	-	-
Barium	µg/L	25	29	45	19	51	9.8	0	11	-	-	-	-	-
Beryllium	µg/L	0.0070	-	<1.0	<0.003	<1.0	-	6	11	-	-	-	-	-
Boron	µg/L	<20	16	23	11	25	5.3	2	11	-	-	-	-	-
Cadmium	µg/L	<0.006	-	0.0060	<0.002	<0.1	-	9	10	-	-	-	-	-
Chromium	µg/L	0.14	-	<0.8	0.080	<0.8	-	6	11	-	-	-	-	-
Cobalt	µg/L	0.070	0.070	0.12	0.040	<0.2	0.024	2	11	-	-	-	-	-
Copper	µg/L	0.15	-	2.5	<0.05	2.5	-	4	11	-	-	-	-	-
Iron	µg/L	300	**609**[(S)]	**1,500**[(S)]	100	**2,000**[(S)]	582	0	11	-	-	-	-	45
Lead	µg/L	0.010	-	<0.1	<0.001	<0.1	-	3	11	-	-	-	-	-
Lithium	µg/L	<6.0	5.2	8.0	3.0	9.0	1.8	1	11	-	-	-	-	-
Manganese	µg/L	20	44	**95**[(S)]	10	**110**[(S)]	33	0	11	-	-	-	-	27
Mercury	µg/L	<0.0012	-	<0.05[(DL >A, DL >C)]	0.00040	.05[(DL >A, DL]	-	7	11	-	-	-	-	-
Methyl mercury	µg/L	0.000040	-	0.000040	-	-	-	0	1	-	-	-	-	-
Molybdenum	µg/L	0.070	0.077	0.12	0.050	0.14	0.027	0	11	-	-	-	-	-
Nickel	µg/L	0.11	-	4.4	<0.005	8.4	-	3	11	-	-	-	-	-
Selenium	µg/L	0.18	-	<0.4	<0.04	<0.4	-	5	11	-	-	-	-	-
Silver	µg/L	0.0050	-	0.11	<0.0005	0.13	-	5	11	-	-	-	-	-
Strontium	µg/L	90	92	125	60	130	22	0	11	-	-	-	-	-
Thallium	µg/L	0.0022	-	<0.1	<0.0003	<0.1	-	7	11	-	-	-	-	-
Titanium	µg/L	1.6	1.6	2.2	<0.5	<5.0	0.60	2	11	-	-	-	-	-
Uranium	µg/L	0.030	0.037	<0.1	0.020	<0.1	0.014	2	11	-	-	-	-	-
Vanadium	µg/L	0.20	0.32	1.00	0.10	1.7	0.46	1	11	-	-	-	-	-
Zinc	µg/L	0.80	0.92	2.8	<0.1	<4.0	0.80	2	11	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	3.0	3.4	5.0	2.0	<10	1.3	1	10	-	-	-	-	-
Antimony	µg/L	0.025	-	<0.4	0.010	<0.4	-	3	10	-	-	-	-	-
Arsenic	µg/L	0.30	0.27	0.50	0.20	0.50	0.095	1	10	-	-	-	-	-
Barium	µg/L	20	26	41	20	50	9.7	0	10	-	-	-	-	-
Beryllium	µg/L	0.0060	-	<0.5	<0.003	<0.5	-	6	10	-	-	-	-	-
Boron	µg/L	20	15	20	10	20	5.3	1	10	-	-	-	-	-
Cadmium	µg/L	<0.006	-	<0.1	<0.002	<0.1	-	10	10	-	-	-	-	-
Chromium	µg/L	0.11	-	0.67	0.040	0.67	-	5	10	-	-	-	-	-
Cobalt	µg/L	0.055	0.054	<0.1	0.030	<0.1	0.016	2	10	-	-	-	-	-
Copper	µg/L	0.20	-	1.9	<0.05	1.9	-	3	10	-	-	-	-	-
Iron	µg/L	185	**345**[(C)]	**1,000**[(C)]	100	**1,000**[(C)]	355	0	10	-	30	-	-	-
Lead	µg/L	0.0050	-	<0.1	<0.001	<0.1	-	5	10	-	-	-	-	-
Lithium	µg/L	4.5	5.0	7.6	3.0	8.0	1.7	0	10	-	-	-	-	-
Manganese	µg/L	14	25	61	3.0	65	23	0	10	-	-	-	-	-
Mercury	µg/L	<0.05	-	<0.05	<0.0006	<0.05	-	5	6	-	-	-	-	-
Molybdenum	µg/L	0.070	0.066	0.12	0.040	0.12	0.024	1	10	-	-	-	-	-
Nickel	µg/L	<0.06	-	0.68	<0.005	0.88	-	6	10	-	-	-	-	-
Selenium	µg/L	0.11	-	<0.4	<0.04	<0.4	-	5	10	-	-	-	-	-
Silver	µg/L	<0.005	-	0.013	<0.0005	0.013	-	7	10	-	-	-	-	-
Strontium	µg/L	85	86	121	60	130	23	0	10	-	-	-	-	-
Thallium	µg/L	0.0020	-	<0.1	<0.0003	<0.1	-	7	10	-	-	-	-	-
Titanium	µg/L	1.4	1.2	1.5	<0.5	1.6	0.42	1	10	-	-	-	-	-
Uranium	µg/L	0.030	0.037	<0.1	0.020	<0.1	0.016	2	10	-	-	-	-	-
Vanadium	µg/L	0.13	0.11	0.14	0.060	<0.2	0.034	2	10	-	-	-	-	-
Zinc	µg/L	0.70	0.65	1.2	<0.05	1.4	0.43	2	10	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (97 to 309 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (6.6 to 8.3). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.40 mg-N/L) is presented and was calculated based on the combination of field pH (8.1) and water temperature (17.4°C). Guidelines calculated with temperature values falling outside the defined range (i.e., 0°C to 30°C) should be used with caution, as the WQG does not necessarily accurately reflect toxic effects at temperature extremes. The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline or below the recommended DO guideline.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
DL>A = Analytical detection limit is higher than the acute aquatic life GOA (2018) guideline.
DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.
- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO =

Table V-6: Operational Phase Seasonal Water Quality Data from the Muskeg River Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	DA (2018) Guidelines for the Protection: Aquatic Life – Acute	Aquatic Life – Chronic	Wildlife Health (Livestock)	Health Canada (2017): Drinking Water MAC	Drinking Water AO	Winter Median	Winter Mean	Winter 95th Percentile	Winter Minimum	Winter Maximum	Winter Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.0	**6.9**[S]	7.5	**4.8**[C, S]	7.8	0.65	0	19	-	11	-	-	42
Specific conductivity	µS/cm	-	-	-	-	-	516	541	756	8.4	800	164	0	19	-	-	-	-	-
Temperature	°C	-	-	-	-	15	0.030	0.42	1.8	-0.16	2.2	0.70	0	19	-	-	-	-	-
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	**5.5**[C]	**5.9**[C]	11	**0.57**[A, C]	12	3.4	0	19	47	63	-	-	-
Conventional Parameters																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.7	7.7	7.9	7.2	8.0	0.25	0	19	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	580	544	683	180	710	118	0	19	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	305	292	367	79	385	67	0	19	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-	300	280	371	67	380	71	0	19	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	320	320	403	120	430	72	0	19	-	-	-	-	-
Total suspended solids	mg/L	-	-	-	-	-	6.0	46	177	<1.0	600	137	1	19	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	17	18	30	10	34	6.2	0	19	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	16	16	28	1.3	30	6.4	0	19	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**35**[S]	**58**[S]	**220**[S]	2.2	**220**[S]	63	0	19	-	-	-	-	95
Major Ions																			
Bicarbonate	mg/L	-	-	-	-	-	370	342	451	82	460	86	0	19	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	74	73	97	19	100	18	0	19	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<0.5	-	<1.0	<0.5	<1.0	-	19	19	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	5.5	9.9	21	<1.0	94	21	2	19	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	27	26	35	8.1	36	6.5	0	19	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	1.7	3.3	13	1.1	20	4.6	0	19	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	4.0	5.2	9.3	1.9	10	2.4	0	19	-	-	-	-	-
Sulphate	mg/L	-	218 to 429[b, c]	1,000	-	500	<1.0	-	89	<1.0	<100	-	14	19	-	-	-	-	-
Sulphide	mg/L	-	.0019 to 0.43	-	-	0.050	0.0027	-	**0.057**[C, S]	<0.0019	**0.12**[C, S]	-	9	19	-	42	-	-	5.0
Nutrients and Biological Indicators																			
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.034	-	0.41	<0.003	2.6	-	5	19	-	-	-	-	-
Total ammonia	mg-N/L	-	0.035[e]	-	-	-	0.67	0.64	1.4	0.12	1.5	0.39	0	19	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	1.2	1.4	2.6	0.68	2.6	0.63	0	19	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	1.3	1.6	2.9	0.72	4.5	0.94	0	19	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.060	0.23	0.98	0.013	1.3	0.35	0	19	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.0080	-	0.38	<0.001	0.78	-	5	19	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	2.5	-	17	<2.0	17	-	6	19	-	-	-	-	-
General Organics																			
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	19	19	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-	<0.002	-	**0.0049**[C, W]	<0.002	**0.0049**[C, W]	-	2	3	-	33	33	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-	**0.0041**[C, W]	-	**0.031**[C, W]	<0.002	**0.042**[C, W]	-	4	16	-	50	75	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	<2.0	<2.0	<2.0	-	19	19	-	-	-	-	-
Total Metals																			
Aluminum	µg/L	-	-	5,000	-	-	21	39	114	4.5	150	39	0	19	-	-	-	-	-
Antimony	µg/L	-	-	-	6.0	-	0.026	-	0.090	<0.02	0.18	-	7	19	-	-	-	-	-
Arsenic	µg/L	-	5.0	25	10	-	0.33	0.45	1.1	0.23	1.2	0.29	0	19	-	-	-	-	-
Barium	µg/L	-	-	-	1,000	-	43	51	83	17	115	23	0	19	-	-	-	-	-
Beryllium	µg/L	-	-	100	-	-	<0.01	-	0.017	<0.01	0.018	-	13	19	-	-	-	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-	<50	-	61	<10	61	-	13	19	-	-	-	-	-
Cadmium	µg/L	1.3 to 7.7[b]	0.11 to 0.37[b]	80	5.0	-	<0.005	-	0.061	<0.005	0.34	-	11	19	-	-	-	-	-
Chromium	µg/L	-	1.0[h]	50	50[h]	-	0.30	-	0.84	<0.1	**1.2**[C]	-	7	19	-	5.0	-	-	-
Cobalt	µg/L	-	0.85 to 1.8[b]	1,000	-	-	0.48	0.57	1.5	0.16	1.6	0.41	0	19	-	-	-	-	-
Copper	µg/L	10 to 60[b]	7.0[b]	500	-	1,000	0.25	0.33	0.75	0.061	1.0	0.28	1	19	-	-	-	-	-
Iron	µg/L	-	-	-	-	300	**2,280**[S]	**5,266**[S]	**17,170**[S]	**749**[S]	**29,500**[S]	7,266	0	19	-	-	-	-	100
Lead	µg/L	-	1.8 to 7.0[b]	100	10	-	0.057	0.27	0.84	<0.005	3.5	0.78	1	19	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	7.0	8.2	15	2.3	27	5.4	0	19	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50	**520**[S]	**640**[S]	**1,320**[S]	**147**[S]	**1,500**[S]	390	0	19	-	-	-	-	100
Mercury	µg/L	0.013	0.0050	3.0	1.0	-	0.00070	0.0011	0.0031	0.00038	**0.0060**[C]	0.0013	3	19	-	5.0	-	-	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-	0.00014	0.00022	0.00087	<0.00003	0.0010	0.00027	4	19	-	-	-	-	-
Molybdenum	µg/L	-	73	500	-	-	<0.05	-	0.25	<0.05	0.37	-	11	19	-	-	-	-	-
Nickel	µg/L	322 to 1,468[b]	36 to 163[b]	1,000	-	-	0.48	0.66	1.3	0.20	2.8	0.57	0	19	-	-	-	-	-
Selenium	µg/L	-	2.0	50	50	-	<0.04	-	0.068	<0.04	0.072	-	12	19	-	-	-	-	-
Silver	µg/L	-	0.25	-	-	-	<0.005	-	0.020	<0.005	0.020	-	17	19	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	134	150	286	36	290	67	0	19	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-	<0.002	-	0.0031	<0.002	0.0036	-	14	19	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	1.1	-	8.9	<0.5	8.9	-	8	19	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-	0.062	0.085	0.20	0.028	0.24	0.058	0	19	-	-	-	-	-
Vanadium	µg/L	-	-	100	-	-	0.30	-	1.4	<0.2	1.5	-	10	19	-	-	-	-	-
Zinc	µg/L	-	30	50,000	-	5,000	2.9	3.9	9.4	0.65	14	3.2	0	19	-	-	-	-	-
Dissolved Metals																			
Aluminum	µg/L	21 to 100[d]	5.8 to 50[d]	-	-	-	3.4	6.6	18	1.2	47	10	0	19	-	-	-	-	-
Antimony	µg/L	-	-	-	-	-	0.020	-	0.048	<0.02	0.12	-	8	19	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-	0.24	0.31	0.55	0.20	0.93	0.18	0	19	-	-	-	-	-
Barium	µg/L	-	-	-	-	-	40	40	64	15	65	12	0	19	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-	<0.01	-	0.010	<0.01	0.010	-	18	19	-	-	-	-	-
Boron	µg/L	-	-	-	-	-	41	-	61	<10	61	-	11	19	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-	<0.005	-	0.026	<0.005	0.14	-	15	19	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-	<0.1	-	0.41	<0.1	0.90	-	12	19	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-	0.32	0.44	1.3	0.11	1.5	0.38	0	19	-	-	-	-	-
Copper	µg/L	-	-	-	-	-	0.13	-	0.90	<0.05	4.5	-	8	19	-	-	-	-	-
Iron	µg/L	-	300	-	-	-	210	**953**[C]	**4,430**[C]	23	**8,300**[C]	2,002	0	19	-	42	-	-	-
Lead	µg/L	-	-	-	-	-	0.010	-	0.56	<0.005	2.5	-	8	19	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	6.0	7.2	13	2.3	13	3.3	0	19	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-	464	530	1,060	50	1,600	379	0	19	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-	0.00056	0.00082	0.0032	0.00015	0.0032	0.00092	2	19	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-	0.060	-	0.36	<0.05	0.39	-	8	19	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-	0.42	0.45	0.82	0.14	0.95	0.20	0	19	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-	<0.04	-	0.062	<0.04	0.083	-	14	19	-	-	-	-	-
Silver	µg/L	-	-	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	19	19	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	132	149	278	36	288	65	0	19	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-	<0.002	-	<0.002	<0.002	<0.002	-	19	19	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	<0.5	-	1.1	<0.5	3.7	-	14	19	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-	0.061	0.081	0.19	0.020	0.23	0.057	0	19	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-	<0.2	-	0.24	<0.2	0.45	-	17	19	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-	1.1	1.9	4.6	0.33	10	2.2	0	19	-	-	-	-	-

Parameter	Spring Median	Spring Mean	Spring 95th Percentile	Spring Minimum	Spring Maximum	Spring Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.2	7.3	7.7	**6.6**[S]	8.2	0.38	0	17	-	-	-	-	18
Specific conductivity	230	238	352	115	383	60	0	17	-	-	-	-	-
Temperature	3.8	5.6	**15**[S]	-3.1	**16**[S]	6.7	0	17	-	-	-	-	6.0
Dissolved oxygen	8.3	8.4	12	**5.4**[C]	14	2.5	0	17	-	29	-	-	-
Conventional Parameters													
pH	7.9	7.9	8.1	7.6	8.1	0.15	0	18	-	-	-	-	-
Specific conductivity	250	238	314	130	450	69	0	18	-	-	-	-	-
Hardness, as $CaCO_3$	120	122	163	64	239	38	0	18	-	-	-	-	-
Total alkalinity, as $CaCO_3$	120	114	144	62	220	34	0	18	-	-	-	-	-
Total dissolved solids	155	162	273	84	290	48	0	18	-	-	-	-	-
Total suspended solids	<1.0	-	9.9	<1.0	13	-	11	18	-	-	-	-	-
Total organic carbon	17	16	20	11	21	3.0	0	18	-	-	-	-	-
Dissolved organic carbon	16	15	19	11	20	2.9	0	18	-	-	-	-	-
Colour	**47**[S]	**51**[S]	**72**[S]	**36**[S]	**75**[S]	12	0	18	-	-	-	-	100
Major Ions													
Bicarbonate	140	138	177	76	270	42	0	18	-	-	-	-	-
Calcium	31	31	44	17	63	10	0	18	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	18	18	-	-	-	-	-
Chloride	2.0	2.3	4.5	1.0	5.6	1.2	0	18	-	-	-	-	-
Magnesium	11	11	14	5.4	22	3.5	0	18	-	-	-	-	-
Potassium	1.7	1.8	2.7	1.3	3.0	0.45	0	18	-	-	-	-	-
Sodium	3.1	3.2	5.1	1.0	6.9	1.3	0	18	-	-	-	-	-
Sulphate	1.6	-	8.6	<1.0	18	-	9	18	-	-	-	-	-
Sulphide	<0.0019	-	0.0030	<0.0019	**0.0050**[C]	-	16	18	-	6.0	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.01	-	0.088	<0.003	0.14	-	12	18	-	-	-	-	-
Total ammonia	<0.05	-	0.084	<0.015	0.20	-	14	18	-	-	-	-	-
Total Kjeldahl nitrogen	0.57	0.61	0.95	0.25	1.2	0.21	0	18	-	-	-	-	-
Total nitrogen (calculated)	0.58	0.63	0.95	0.39	1.2	0.19	0	18	-	-	-	-	-
Total phosphorus	0.023	0.034	0.071	0.010	0.13	0.029	0	18	-	-	-	-	-
Dissolved phosphorus	0.012	0.014	0.032	0.0023	0.057	0.012	0	18	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	3.4	<2.0	6.3	-	12	18	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	17	17	-	-	-	-	-
Phenol[f]	<0.002	-	**0.0044**[C, W]	<0.002	**0.0044**[C, W]	-	7	8	-	13	13	-	-
Total phenolics[g]	**0.0039**[W]	**0.0060**[C, W]	**0.017**[C, W]	**0.0025**[W]	**0.026**[C, W]	0.0071	0	10	-	50	100	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	18	18	-	-	-	-	-
Total Metals													
Aluminum	17	27	77	5.9	119	29	0	18	-	-	-	-	-
Antimony	0.028	-	<0.05	<0.02	<0.05	-	7	18	-	-	-	-	-
Arsenic	0.26	0.27	0.37	0.18	0.45	0.065	0	18	-	-	-	-	-
Barium	22	22	29	14	30	4.7	0	18	-	-	-	-	-
Beryllium	<0.01	-	0.010	<0.01	0.010	-	17	18	-	-	-	-	-
Boron	19	-	<50	9.0	<50	-	10	18	-	-	-	-	-
Cadmium	<0.005	-	0.015	<0.005	0.023	-	15	18	-	-	-	-	-
Chromium	<0.1	-	<0.5	<0.1	<0.5	-	15	18	-	-	-	-	-
Cobalt	0.080	0.11	0.25	0.057	0.34	0.075	0	18	-	-	-	-	-
Copper	0.18	0.21	0.41	0.060	0.45	0.13	2	18	-	-	-	-	-
Iron	**395**[S]	**612**[S]	**1,530**[S]	150	**1,700**[S]	479	0	18	-	-	-	-	67
Lead	0.024	-	0.13	0.010	0.27	-	6	18	-	-	-	-	-
Lithium	3.7	3.7	5.6	1.0	6.8	1.2	0	18	-	-	-	-	-
Manganese	30	**85**[S]	**301**[S]	10	**420**[S]	112	0	18	-	-	-	-	39
Mercury	<0.001	0.0012	0.0031	<0.0006	**0.0060**[C]	0.0013	4	18	-	6.0	-	-	-
Methyl mercury	0.000090	-	0.00021	0.000050	0.00026	-	7	18	-	-	-	-	-
Molybdenum	0.16	0.15	0.21	0.070	0.27	0.048	0	18	-	-	-	-	-
Nickel	0.46	0.47	0.65	0.31	0.66	0.10	0	18	-	-	-	-	-
Selenium	<0.04	-	0.052	<0.04	0.063	-	15	18	-	-	-	-	-
Silver	<0.005	-	0.013	<0.005	0.013	-	16	18	-	-	-	-	-
Strontium	61	62	91	30	99	17	0	18	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	16	18	-	-	-	-	-
Titanium	1.2	-	<5.0	<0.5	<5.0	-	8	18	-	-	-	-	-
Uranium	0.037	0.046	0.096	0.017	0.12	0.028	0	18	-	-	-	-	-
Vanadium	<0.2	-	<0.5	<0.2	<0.5	-	12	18	-	-	-	-	-
Zinc	1.3	1.9	4.5	0.40	6.3	1.6	2	18	-	-	-	-	-
Dissolved Metals													
Aluminum	4.1	5.0	9.7	2.0	14	2.9	0	18	-	-	-	-	-
Antimony	0.020	-	0.034	<0.02	0.047	-	5	18	-	-	-	-	-
Arsenic	0.23	0.24	0.32	0.18	0.33	0.048	0	18	-	-	-	-	-
Barium	20	20	29	10	30	5.0	0	18	-	-	-	-	-
Beryllium	<0.01	-	0.039	<0.01	0.039	-	17	18	-	-	-	-	-
Boron	15	-	<50	<10	<50	-	10	18	-	-	-	-	-
Cadmium	<0.005	-	0.0068	<0.005	0.011	-	15	18	-	-	-	-	-
Chromium	<0.1	-	0.10	<0.1	0.10	-	17	18	-	-	-	-	-
Cobalt	0.053	0.067	0.18	0.032	0.27	0.058	0	18	-	-	-	-	-
Copper	0.13	0.44	1.6	<0.05	2.2	0.63	4	18	-	-	-	-	-
Iron	185	285	**618**[C]	69	**1,000**[C]	238	0	18	-	39	-	-	-
Lead	0.0084	-	0.048	<0.005	0.063	-	7	18	-	-	-	-	-
Lithium	3.7	3.8	5.4	1.0	7.5	1.4	0	18	-	-	-	-	-
Manganese	6.2	31	114	0.29	300	71	0	18	-	-	-	-	-
Mercury	0.00061	0.00075	0.0017	0.00047	0.0020	0.00044	2	18	-	-	-	-	-
Molybdenum	0.14	0.15	0.24	0.070	0.26	0.053	0	18	-	-	-	-	-
Nickel	0.41	0.48	0.75	0.26	0.93	0.18	0	18	-	-	-	-	-
Selenium	<0.04	-	0.051	<0.04	0.055	-	14	18	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	18	18	-	-	-	-	-
Strontium	60	61	96	30	100	17	0	18	-	-	-	-	-
Thallium	<0.002	-	<0.002	<0.002	<0.002	-	18	18	-	-	-	-	-
Titanium	<0.5	-	0.56	<0.5	0.56	-	17	18	-	-	-	-	-
Uranium	0.036	0.043	0.089	0.010	0.11	0.027	0	18	-	-	-	-	-
Vanadium	<0.2	-	0.25	<0.2	0.25	-	17	18	-	-	-	-	-
Zinc	0.75	1.0	2.7	0.11	4.8	1.1	0	18	-	-	-	-	-

Parameter	Summer Median	Summer Mean	Summer 95th Percentile	Summer Minimum	Summer Maximum	Summer Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.1	7.1	8.4	**5.0**[C, S]	**9.6**[C]	0.96	0	16	-	19	-	-	44
Specific conductivity	427	388	498	169	503	108	0	17	-	-	-	-	-
Temperature	15	15	**19**[S]	11	**19**[S]	2.7	0	17	-	-	-	-	41
Dissolved oxygen	**3.9**[A, C]	**3.8**[A, C]	7.5	**0.49**[A, C]	8.0	2.5	0	17	65	82	-	-	-
Conventional Parameters													
pH	7.9	7.9	8.2	7.5	8.2	0.20	0	17	-	-	-	-	-
Specific conductivity	430	404	510	250	510	86	0	17	-	-	-	-	-
Hardness, as $CaCO_3$	240	225	290	137	290	54	0	17	-	-	-	-	-
Total alkalinity, as $CaCO_3$	230	214	262	120	270	49	0	17	-	-	-	-	-
Total dissolved solids	280	278	340	190	340	50	0	17	-	-	-	-	-
Total suspended solids	2.0	-	32	<1.0	34	-	6	17	-	-	-	-	-
Total organic carbon	27	32	49	22	120	23	0	17	-	-	-	-	-
Dissolved organic carbon	25	25	31	13	31	4.4	0	17	-	-	-	-	-
Colour	**84**[S]	**78**[S]	**124**[S]	**25**[S]	**140**[S]	34	0	17	-	-	-	-	100
Major Ions													
Bicarbonate	280	259	322	150	330	60	0	17	-	-	-	-	-
Calcium	59	58	78	34	82	15	0	17	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	17	17	-	-	-	-	-
Chloride	2.0	2.3	3.6	1.1	4.2	0.76	0	17	-	-	-	-	-
Magnesium	20	19	24	12	25	3.9	0	17	-	-	-	-	-
Potassium	0.77	0.82	1.3	0.20	1.6	0.33	0	17	-	-	-	-	-
Sodium	4.2	4.5	7.1	3.0	7.6	1.4	0	17	-	-	-	-	-
Sulphate	<1.0	-	12	0.60	12	-	15	17	-	-	-	-	-
Sulphide	**0.0056**[C]	-	**0.035**[C]	<0.0019	**0.041**[C]	-	5	17	-	59	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.014	-	0.022	<0.003	0.022	-	14	17	-	-	-	-	-
Total ammonia	0.080	0.088	0.19	0.029	0.24	0.064	4	17	-	-	-	-	-
Total Kjeldahl nitrogen	1.0	1.1	1.5	0.66	1.6	0.26	0	17	-	-	-	-	-
Total nitrogen (calculated)	1.0	1.1	1.5	0.66	1.6	0.26	0	17	-	-	-	-	-
Total phosphorus	0.047	0.064	0.15	0.017	0.28	0.064	0	17	-	-	-	-	-
Dissolved phosphorus	0.022	0.024	0.056	<0.001	0.071	0.018	1	17	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	5.2	<2.0	6.4	-	9	17	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	17	17	-	-	-	-	-
Phenol[f]	**0.0078**[C, W]	-	**0.0095**[C, W]	<0.002	**0.0096**[C, W]	-	3	6	-	50	50	-	-
Total phenolics[g]	**0.0026**[W]	-	**0.0045**[C, W]	<0.002	**0.0050**[C, W]	-	4	11	-	9.0	64	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	17	17	-	-	-	-	-
Total Metals													
Aluminum	12	20	66	5.0	70	20	0	17	-	-	-	-	-
Antimony	0.030	0.029	0.046	<0.02	0.070	0.014	3	17	-	-	-	-	-
Arsenic	0.60	0.73	1.4	0.45	1.4	0.32	0	17	-	-	-	-	-
Barium	44	41	57	19	62	13	0	17	-	-	-	-	-
Beryllium	<0.01	-	0.014	<0.01	0.014	-	16	17	-	-	-	-	-
Boron	<20	-	<50	<10	<50	-	7	17	-	-	-	-	-
Cadmium	<0.005	-	0.013	<0.005	0.019	-	14	17	-	-	-	-	-
Chromium	<0.1	-	0.20	<0.1	0.20	-	9	17	-	-	-	-	-
Cobalt	0.30	0.35	0.73	0.12	0.86	0.23	0	17	-	-	-	-	-
Copper	0.15	-	0.51	<0.05	0.64	-	5	17	-	-	-	-	-
Iron	**1,000**[S]	**2,015**[S]	**4,666**[S]	233	**4,930**[S]	1,649	0	17	-	-	-	-	88
Lead	<0.02	-	0.090	<0.005	0.090	-	7	17	-	-	-	-	-
Lithium	5.0	5.5	8.5	3.7	9.9	1.7	0	17	-	-	-	-	-
Manganese	**506**[S]	**466**[S]	**928**[S]	50	**1,200**[S]	387	0	17	-	-	-	-	94
Mercury	0.0012	0.0011	0.0017	<0.0006	0.0019	0.00043	2	17	-	-	-	-	-
Methyl mercury	0.00027	0.00028	0.00053	<0.00003	0.00055	0.00014	1	17	-	-	-	-	-
Molybdenum	0.097	0.100	0.17	<0.05	0.21	0.050	3	17	-	-	-	-	-
Nickel	0.71	0.69	0.94	0.39	0.96	0.18	0	17	-	-	-	-	-
Selenium	0.070	0.059	0.082	<0.04	0.098	0.023	3	17	-	-	-	-	-
Silver	<0.01	-	0.036	<0.005	0.036	-	16	17	-	-	-	-	-
Strontium	117	122	184	80	199	35	0	17	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	13	17	-	-	-	-	-
Titanium	<2.0	-	<2.0	<0.5	<2.0	-	13	17	-	-	-	-	-
Uranium	0.036	0.043	0.080	0.014	0.10	0.022	0	17	-	-	-	-	-
Vanadium	<0.2	-	0.33	<0.2	0.39	-	11	17	-	-	-	-	-
Zinc	1.6	2.6	6.7	0.70	11	2.6	2	17	-	-	-	-	-
Dissolved Metals													
Aluminum	4.3	4.7	7.8	1.4	9.0	2.2	0	17	-	-	-	-	-
Antimony	0.030	0.030	0.048	<0.02	0.050	0.011	2	17	-	-	-	-	-
Arsenic	0.53	0.59	0.94	0.36	1.0	0.19	0	17	-	-	-	-	-
Barium	41	37	47	20	52	9.0	0	17	-	-	-	-	-
Beryllium	<0.01	-	0.011	<0.01	0.011	-	16	17	-	-	-	-	-
Boron	18	-	<50	<10	<50	-	8	17	-	-	-	-	-
Cadmium	<0.005	-	0.0084	<0.005	0.0084	-	16	17	-	-	-	-	-
Chromium	<0.1	-	0.11	<0.1	0.12	-	14	17	-	-	-	-	-
Cobalt	0.13	0.19	0.47	0.053	0.48	0.14	0	17	-	-	-	-	-
Copper	<0.05	-	0.23	<0.05	0.60	-	11	17	-	-	-	-	-
Iron	**571**[C]	**746**[C]	**1,740**[C]	39	**1,900**[C]	621	0	17	-	65	-	-	-
Lead	<0.005	-	0.036	<0.005	0.068	-	11	17	-	-	-	-	-
Lithium	5.0	5.5	8.2	3.7	10	1.7	0	17	-	-	-	-	-
Manganese	68	194	618	0.20	960	275	0	17	-	-	-	-	-
Mercury	0.00081	0.0010	0.0021	0.00044	0.0031	0.00070	1	17	-	-	-	-	-
Molybdenum	0.090	0.100	0.20	<0.05	0.23	0.055	3	17	-	-	-	-	-
Nickel	0.68	0.68	1.1	0.32	1.5	0.27	0	17	-	-	-	-	-
Selenium	0.058	0.056	0.081	<0.04	0.085	0.019	2	17	-	-	-	-	-
Silver	<0.005	-	0.0050	<0.005	0.0050	-	16	17	-	-	-	-	-
Strontium	124	123	174	80	188	33	0	17	-	-	-	-	-
Thallium	<0.002	-	<0.002	<0.002	<0.002	-	17	17	-	-	-	-	-
Titanium	<0.5	-	<0.5	<0.5	<0.5	-	17	17	-	-	-	-	-
Uranium	0.032	0.040	0.080	0.014	0.10	0.022	0	17	-	-	-	-	-
Vanadium	<0.2	-	0.21	<0.2	0.23	-	14	17	-	-	-	-	-
Zinc	0.60	1.5	5.8	0.20	8.8	2.2	0	17	-	-	-	-	-

Table V-6: Operational Phase Seasonal Water Quality Data from the Muskeg River Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
										A	C	W	D	S
Field Measured														
pH	-	7.0	**6.8**$^{(S)}$	7.6	**4.7**$^{(C, S)}$	7.6	0.79	0	11	-	18	-	-	45
Specific conductivity	µS/cm	352	387	644	225	886	171	0	12	-	-	-	-	-
Temperature	°C	2.7	4.1	12	0.97	12	3.9	0	12	-	-	-	-	-
Dissolved oxygen	mg/L	6.6	7.0	11	**3.0**$^{(A, C)}$	11	2.8	0	12	33	50	-	-	-
Conventional Parameters														
pH	-	7.9	7.9	8.2	7.5	8.2	0.23	0	14	-	-	-	-	-
Specific conductivity	µS/cm	340	371	521	225	524	103	0	14	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	185	195	270	111	280	54	0	14	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	180	184	278	99	292	56	0	14	-	-	-	-	-
Total dissolved solids	mg/L	215	239	320	183	320	53	0	14	-	-	-	-	-
Total suspended solids	mg/L	4.4	6.5	18	<1.0	20	6.3	3	14	-	-	-	-	-
Total organic carbon	mg/L	20	21	29	17	36	4.9	0	14	-	-	-	-	-
Dissolved organic carbon	mg/L	20	21	28	16	36	4.8	0	14	-	-	-	-	-
Colour	TCU	**51**$^{(S)}$	**63**$^{(S)}$	**114**$^{(S)}$	**34**$^{(S)}$	**143**$^{(S)}$	29	0	14	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	220	225	339	121	356	68	0	14	-	-	-	-	-
Calcium	mg/L	46	51	71	27	76	15	0	14	-	-	-	-	-
Carbonate	mg/L	<1.0	-	5.0	<0.5	5.0	-	13	14	-	-	-	-	-
Chloride	mg/L	2.8	3.2	5.6	1.0	5.7	1.6	0	14	-	-	-	-	-
Magnesium	mg/L	17	17	23	10	24	4.4	0	14	-	-	-	-	-
Potassium	mg/L	1.1	1.2	2.2	0.75	2.4	0.54	0	14	-	-	-	-	-
Sodium	mg/L	4.2	5.2	9.3	3.0	9.8	2.1	0	14	-	-	-	-	-
Sulphate	mg/L	<1.0	-	40	<1.0	41	-	9	14	-	-	-	-	-
Sulphide	mg/L	**0.0041**$^{(C)}$	-	**0.0096**$^{(C)}$	<0.0019	**0.011**$^{(C)}$	-	5	14	-	57	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.014	-	0.071	<0.01	0.071	-	11	14	-	-	-	-	-
Total ammonia	mg-N/L	0.060	0.088	0.22	0.022	0.45	0.11	2	14	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.76	0.77	1.1	0.54	1.3	0.22	0	14	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.76	0.78	1.1	0.54	1.3	0.22	0	14	-	-	-	-	-
Total phosphorus	mg-P/L	0.033	0.041	0.092	0.011	0.11	0.029	0	14	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.014	0.016	0.034	0.0061	0.039	0.0095	0	14	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	3.4	<2.0	5.8	-	11	14	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	<1.0	-	<1.0	0.20	<1.0	-	12	14	-	-	-	-	-
Phenol[t]	mg/L	<0.002	-	<0.002	<0.002	<0.002	-	7	7	-	-	-	-	-
Total phenolics[u]	mg/L	**0.0040**$^{(W)}$	-	**0.0099**$^{(C, W)}$	<0.002	**0.012**$^{(C, W)}$	-	2	7	-	29	71	-	-
Total recoverable hydrocarbons	mg/L	<2.0	-	<2.0	<1.0	<2.0	-	14	14	-	-	-	-	-
Total Metals														
Aluminum	µg/L	17	32	100	<3.0	100	36	1	14	-	-	-	-	-
Antimony	µg/L	0.029	-	0.050	<0.02	0.050	-	6	14	-	-	-	-	-
Arsenic	µg/L	0.33	0.35	0.50	0.19	0.56	0.097	0	14	-	-	-	-	-
Barium	µg/L	28	29	45	18	50	9.9	0	14	-	-	-	-	-
Beryllium	µg/L	<0.01	-	0.10	<0.01	0.10	-	13	14	-	-	-	-	-
Boron	µg/L	19	-	<50	<10	<50	-	9	14	-	-	-	-	-
Cadmium	µg/L	<0.005	-	0.010	<0.005	<0.1	-	10	14	-	-	-	-	-
Chromium	µg/L	0.12	-	0.30	<0.1	<0.5	-	7	14	-	-	-	-	-
Cobalt	µg/L	0.10	0.14	0.26	0.064	0.27	0.076	1	14	-	-	-	-	-
Copper	µg/L	0.29	0.28	0.59	0.096	0.64	0.19	3	14	-	-	-	-	-
Iron	µg/L	**673**$^{(S)}$	**1,053**$^{(S)}$	**2,957**$^{(S)}$	100	**4,900**$^{(S)}$	1,231	0	14	-	-	-	-	79
Lead	µg/L	0.043	-	0.10	<0.02	0.11	-	4	14	-	-	-	-	-
Lithium	µg/L	5.0	6.0	11	3.9	11	2.6	0	14	-	-	-	-	-
Manganese	µg/L	**100**$^{(S)}$	**128**$^{(S)}$	**277**$^{(S)}$	10	**420**$^{(S)}$	104	0	14	-	-	-	-	79
Mercury	µg/L	0.00070	0.00082	0.0014	0.00042	0.0018	0.00037	0	14	-	-	-	-	-
Methyl mercury	µg/L	0.00013	0.00014	0.00025	<0.00008	0.00026	0.000068	1	12	-	-	-	-	-
Molybdenum	µg/L	0.091	0.088	0.15	<0.05	0.15	0.037	2	14	-	-	-	-	-
Nickel	µg/L	0.39	0.43	0.70	<0.1	0.74	0.21	1	14	-	-	-	-	-
Selenium	µg/L	<0.04	-	0.30	<0.04	0.30	-	11	14	-	-	-	-	-
Silver	µg/L	<0.01	-	0.011	<0.005	0.012	-	11	14	-	-	-	-	-
Strontium	µg/L	88	101	166	50	174	39	0	14	-	-	-	-	-
Thallium	µg/L	<0.002	-	0.10	<0.002	0.10	-	10	14	-	-	-	-	-
Titanium	µg/L	<2.0	-	2.6	<0.5	<5.0	-	8	14	-	-	-	-	-
Uranium	µg/L	0.040	0.055	0.10	0.025	0.11	0.030	0	14	-	-	-	-	-
Vanadium	µg/L	0.20	-	0.42	<0.1	0.56	-	7	14	-	-	-	-	-
Zinc	µg/L	1.8	1.7	3.0	0.70	3.3	0.95	3	14	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	3.2	3.9	7.4	1.0	10	2.3	0	14	-	7.0	-	-	-
Antimony	µg/L	0.024	-	0.050	<0.02	0.050	-	5	14	-	-	-	-	-
Arsenic	µg/L	0.28	0.31	0.45	0.24	0.55	0.085	0	14	-	-	-	-	-
Barium	µg/L	26	28	43	18	49	9.4	0	14	-	-	-	-	-
Beryllium	µg/L	<0.01	-	0.10	<0.01	0.10	-	13	14	-	-	-	-	-
Boron	µg/L	<20	-	24	<10	<50	-	9	14	-	-	-	-	-
Cadmium	µg/L	<0.005	-	0.010	<0.005	<0.1	-	13	14	-	-	-	-	-
Chromium	µg/L	<0.1	-	0.30	<0.1	0.30	-	11	14	-	-	-	-	-
Cobalt	µg/L	0.093	0.10	0.23	0.027	0.26	0.068	1	14	-	-	-	-	-
Copper	µg/L	0.065	-	0.40	<0.05	0.40	-	6	14	-	-	-	-	-
Iron	µg/L	297	297	**574**$^{(C)}$	<4.0	**780**$^{(C)}$	205	1	14	-	50	-	-	-
Lead	µg/L	0.0060	-	0.10	<0.005	0.10	-	8	14	-	-	-	-	-
Lithium	µg/L	5.1	6.2	11	4.0	12	2.6	0	14	-	-	-	-	-
Manganese	µg/L	65	95	278	0.38	440	116	0	14	-	-	-	-	-
Mercury	µg/L	0.00036	0.0057	0.050	0.00027	0.050	0.014	1	14	-	-	-	-	-
Molybdenum	µg/L	0.091	0.094	0.18	<0.05	0.20	0.051	3	14	-	-	-	-	-
Nickel	µg/L	0.36	0.42	0.88	<0.1	1.3	0.30	1	14	-	-	-	-	-
Selenium	µg/L	<0.04	-	0.30	<0.04	0.30	-	11	14	-	-	-	-	-
Silver	µg/L	<0.005	-	0.010	<0.005	0.010	-	13	14	-	-	-	-	-
Strontium	µg/L	90	102	167	50	170	38	0	14	-	-	-	-	-
Thallium	µg/L	<0.002	-	0.10	<0.002	0.10	-	12	14	-	-	-	-	-
Titanium	µg/L	<0.5	-	0.90	<0.5	0.90	-	12	14	-	-	-	-	-
Uranium	µg/L	0.042	0.053	0.10	0.024	0.10	0.028	0	14	-	-	-	-	-
Vanadium	µg/L	<0.2	-	0.20	<0.1	0.20	-	12	14	-	-	-	-	-
Zinc	µg/L	0.69	1.2	3.7	0.21	6.5	1.6	0	14	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (64 to 385 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (4.7 to 9.6). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.035 mg-N/L) is presented and was calculated based on the combination of field pH (9.6) and water temperature (10.9°C). Guidelines calculated with temperature and pH values falling outside the defined range (i.e., pH 6.0 to 10.0 and temperature 0°C to 30°C) should be used with caution, as the WQG does not necessarily accurately reflect toxic effects at the low and high pH and temperature extremes. The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline, below the recommended DO guideline, or outside the recommended pH range.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.
- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO = dissolved oxygen.

Table V-7: Baseline Phase Seasonal Water Quality Data from the Wapasu Creek Watershed Compared to Guidelines, 2007 to 2010

Parameter	Unit	GOA (2018) Guidelines for the Protection of:			Health Canada (2017)		Seasonal Summary													Seasonal Summary													Seasonal Summary												
		Aquatic Life		Wildlife Health (Livestock)	Drinking Water MAC	Drinking Water AO	Winter													Spring													Summer												
		Acute	Chronic				Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline					Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline					Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
															A	C	W	D	S									A	C	W	D	S									A	C	W	D	S
Field Measured																																													
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.5	-	7.5	-	-	-	0	1	-	-	-	-	-	**6.9[S]**	-	**6.9[S]**	-	-	-	0	1	-	-	-	-	100	**6.9[S]**	**6.9[S]**	**6.9[S]**	**6.9[S]**	**6.9[S]**	0	0	2	-	-	-	-	100
Specific conductivity	µS/cm	-	-	-	-	-	406	-	406	-	-	-	0	1	-	-	-	-	-	120	-	120	-	-	-	0	1	-	-	-	-	-	337	337	444	217	456	169	0	2	-	-	-	-	-
Temperature	°C	-	-	-	-	15	1.0	-	1.0	-	-	-	0	1	-	-	-	-	-	4.3	-	4.3	-	-	-	0	1	-	-	-	-	-	**16[S]**	**16[S]**	**17[S]**	**15[S]**	**17[S]**	1.4	0	2	-	-	-	-	100
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	8.2	-	8.2	-	-	-	0	1	-	-	-	-	-	10	-	10	-	-	-	0	1	-	-	-	-	-	7.3	7.3	7.6	6.9	7.6	0.49	0	2	-	-	-	-	-
Conventional Parameters																																													
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.4	-	7.4	-	-	-	0	1	-	-	-	-	-	7.5	-	7.5	-	-	-	0	1	-	-	-	-	-	7.9	7.9	7.9	7.8	7.9	0.071	0	2	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	340	-	340	-	-	-	0	1	-	-	-	-	-	130	-	130	-	-	-	0	1	-	-	-	-	-	210	210	237	179	240	43	0	2	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	254	-	254	-	-	-	0	1	-	-	-	-	-	61	-	61	-	-	-	0	1	-	-	-	-	-	107	107	124	87	126	28	0	2	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[a]	-	-	-	170	-	170	-	-	-	0	1	-	-	-	-	-	63	-	63	-	-	-	0	1	-	-	-	-	-	112	112	128	93	130	26	0	2	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	230	-	230	-	-	-	0	1	-	-	-	-	-	110	-	110	-	-	-	0	1	-	-	-	-	-	178	178	189	166	190	17	0	2	-	-	-	-	-
Total suspended solids	mg/L	-	-	-	-	-	35	-	35	-	-	-	0	1	-	-	-	-	-	3.0	-	3.0	-	-	-	0	1	-	-	-	-	-	9.0	-	9.0	<3.0	9.0	-	1	2	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	14	-	14	-	-	-	0	1	-	-	-	-	-	16	-	16	-	-	-	0	1	-	-	-	-	-	32	32	35	28	35	4.9	0	2	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	14	-	14	-	-	-	0	1	-	-	-	-	-	15	-	15	-	-	-	0	1	-	-	-	-	-	30	30	35	25	35	7.1	0	2	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**51[S]**	-	**51[S]**	-	-	-	0	1	-	-	-	-	100	**47[S]**	-	**47[S]**	-	-	-	0	1	-	-	-	-	100	**135[S]**	**135[S]**	**174[S]**	**91[S]**	**178[S]**	62	0	2	-	-	-	-	100
Major Ions																																													
Bicarbonate	mg/L	-	-	-	-	-	210	-	210	-	-	-	0	1	-	-	-	-	-	77	-	77	-	-	-	0	1	-	-	-	-	-	137	137	158	113	160	33	0	2	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	44	-	44	-	-	-	0	1	-	-	-	-	-	17	-	17	-	-	-	0	1	-	-	-	-	-	30	30	36	23	37	9.9	0	2	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<0.5	-	<0.5	-	-	-	1	1	-	-	-	-	-	<0.5	-	<0.5	-	-	-	1	1	-	-	-	-	-	<5.0	-	<5.0	<0.5	<5.0	-	2	2	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	7.0	-	7.0	-	-	-	0	1	-	-	-	-	-	3.0	-	3.0	-	-	-	0	1	-	-	-	-	-	3.0	-	3.0	<1.0	3.0	-	1	2	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	14	-	14	-	-	-	0	1	-	-	-	-	-	5.9	-	5.9	-	-	-	0	1	-	-	-	-	-	9.0	9.0	11	7.0	11	2.8	0	2	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	2.7	-	2.7	-	-	-	0	1	-	-	-	-	-	1.5	-	1.5	-	-	-	0	1	-	-	-	-	-	0.40	-	0.40	0.40	<0.5	-	1	2	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	6.0	-	6.0	-	-	-	0	1	-	-	-	-	-	5.0	-	5.0	-	-	-	0	1	-	-	-	-	-	5.5	5.5	6.0	5.0	6.0	0.71	0	2	-	-	-	-	-
Sulphate	mg/L	-	218 to 429[b, c]	1,000	-	500	2.0	-	2.0	-	-	-	0	1	-	-	-	-	-	<1.0	-	<1.0	-	-	-	1	1	-	-	-	-	-	1.0	-	1.0	<1.0	1.0	-	1	2	-	-	-	-	-
Sulphide	mg/L	-	0.0027 to 0.015[d]	-	-	0.050	**0.0080[C]**	-	**0.0080[C]**	-	-	-	0	1	-	100	-	-	-	**0.010[C]**	-	**0.010[C]**	-	-	-	0	1	-	100	-	-	-	**0.015[C]**	**0.015[C]**	**0.017[C]**	**0.013[C]**	**0.017[C]**	0.0026	0	2	-	100	-	-	-
Nutrients and Biological Indicators																																													
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.16	-	0.16	-	-	-	0	1	-	-	-	-	-	<0.003	-	<0.003	-	-	-	1	1	-	-	-	-	-	0.011	-	0.011	0.011	<0.071	-	1	2	-	-	-	-	-
Total ammonia	mg-N/L	-	0.79[e]	-	-	-	0.45	-	0.45	-	-	-	0	1	-	-	-	-	-	<0.05	-	<0.05	-	-	-	1	1	-	-	-	-	-	0.080	-	0.080	<0.05	0.080	-	1	2	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	1.1	-	1.1	-	-	-	0	1	-	-	-	-	-	0.70	-	0.70	-	-	-	0	1	-	-	-	-	-	1.5	1.5	1.8	1.2	1.8	0.42	0	2	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	1.3	-	1.3	-	-	-	0	1	-	-	-	-	-	0.70	-	0.70	-	-	-	0	1	-	-	-	-	-	1.5	1.5	1.8	1.2	1.8	0.42	0	2	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.030	-	0.030	-	-	-	0	1	-	-	-	-	-	0.020	-	0.020	-	-	-	0	1	-	-	-	-	-	0.025	0.025	0.030	0.020	0.030	0.0071	0	2	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.022	-	0.022	-	-	-	0	1	-	-	-	-	-	0.012	-	0.012	-	-	-	0	1	-	-	-	-	-	0.018	0.018	0.022	0.014	0.022	0.0057	0	2	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	4.0	-	4.0	-	-	-	0	1	-	-	-	-	-	<4.0	-	<4.0	-	-	-	1	1	-	-	-	-	-	<2.0	-	<2.0	<2.0	<2.0	-	2	2	-	-	-	-	-
General Organics																																													
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	-	-	-	1	1	-	-	-	-	-	<1.0	-	<1.0	-	-	-	1	1	-	-	-	-	-	1.3	-	1.3	<1.0	1.3	-	1	2	-	-	-	-	-
Phenol[f]	mg/L	-	0.0040	0.0020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics[g]	mg/L	-	0.0040	0.0020	-	-	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-	**0.0055[C, W]**	**0.0055[C, W]**	**0.0078[C, W]**	**0.0030[W]**	**0.0080[C, W]**	0.0035	0	2	-	50	100	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	<2.0	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	<2.0	-	<2.0	-	-	-	1	1	-	-	-	-	-
Total Metals																																													
Aluminum	µg/L	-	-	5,000	-	-	120	-	120	-	-	-	0	1	-	-	-	-	-	20	-	20	-	-	-	0	1	-	-	-	-	-	30	30	48	10	50	28	0	2	-	-	-	-	-
Antimony	µg/L	-	-	-	6.0	-	0.040	-	0.040	-	-	-	0	1	-	-	-	-	-	<0.02	-	<0.02	-	-	-	1	1	-	-	-	-	-	0.020	-	0.020	0.020	<0.4	-	1	2	-	-	-	-	-
Arsenic	µg/L	-	5.0	25	10	-	0.30	-	0.30	-	-	-	0	1	-	-	-	-	-	0.20	-	0.20	-	-	-	0	1	-	-	-	-	-	0.40	0.40	0.40	0.40	0.40	0	0	2	-	-	-	-	-
Barium	µg/L	-	-	-	1,000	-	50	-	50	-	-	-	0	1	-	-	-	-	-	10	-	10	-	-	-	0	1	-	-	-	-	-	25	25	30	20	30	7.1	0	2	-	-	-	-	-
Beryllium	µg/L	-	-	100	-	-	0.020	-	0.020	-	-	-	0	1	-	-	-	-	-	<0.01	-	<0.01	-	-	-	1	1	-	-	-	-	-	<1.0	-	<1.0	<0.01	<1.0	-	2	2	-	-	-	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-	<50	-	<50	-	-	-	1	1	-	-	-	-	-	<50	-	<50	-	-	-	1	1	-	-	-	-	-	30	-	30	30	<50	-	1	2	-	-	-	-	-
Cadmium	µg/L	1.3 to 5.4[b]	0.11 to 0.34[b]	80	5.0	-	0.0060	-	0.0060	-	-	-	0	1	-	-	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-
Chromium	µg/L	-	1.0[h]	50	50[h]	-	0.30	-	0.30	-	-	-	0	1	-	-	-	-	-	<0.1	-	<0.1	-	-	-	1	1	-	-	-	-	-	0.10	-	0.10	0.10	<0.8	-	1	2	-	-	-	-	-
Cobalt	µg/L	-	0.83 to 1.5[b]	1,000	-	-	0.48	-	0.48	-	-	-	0	1	-	-	-	-	-	0.060	-	0.060	-	-	-	0	1	-	-	-	-	-	0.15	-	0.15	0.15	<0.2	-	1	2	-	-	-	-	-
Copper	µg/L	9.9 to 40[b]	7.0[b]	500	-	1,000	0.50	-	0.50	-	-	-	0	1	-	-	-	-	-	0.10	-	0.10	-	-	-	0	1	-	-	-	-	-	0.20	-	0.20	0.20	<1.0	-	1	2	-	-	-	-	-
Iron	µg/L	-	-	-	-	300	**2,000[S]**	-	**2,000[S]**	-	-	-	0	1	-	-	-	-	100	100	-	100	-	-	-	0	1	-	-	-	-	-	**1,000[S]**	**1,000[S]**	**1,000[S]**	**1,000[S]**	**1,000[S]**	0	0	2	-	-	-	-	100
Lead	µg/L	-	1.7 to 7.0[b]	100	10	-	0.59	-	0.59	-	-	-	0	1	-	-	-	-	-	0.030	-	0.030	-	-	-	0	1	-	-	-	-	-	0.020	-	0.020	0.020	<0.1	-	1	2	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	11	-	11	-	-	-	0	1	-	-	-	-	-	5.0	-	5.0	-	-	-	0	1	-	-	-	-	-	6.0	-	6.0	<6.0	6.0	-	1	2	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50	**420[S]**	-	**420[S]**	-	-	-	0	1	-	-	-	-	100	10	-	10	-	-	-	0	1	-	-	-	-	-	**60[S]**	**60[S]**	**87[S]**	30	**90[S]**	42	0	2	-	-	-	-	50
Mercury	µg/L	0.013	0.0050	3.0	1.0	-	<0.0006	-	<0.0006	-	-	-	1	1	-	-	-	-	-	0.0010	-	0.0010	-	-	-	0	1	-	-	-	-	-	0.0010	0.0010	0.0010	0.0010	0.0010	0	0	2	-	-	-	-	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-	0.000070	-	0.000070	-	-	-	0	1	-	-	-	-	-	<0.00003	-	<0.00003	-	-	-	1	1	-	-	-	-	-	0.00017	0.00017	0.00028	0.000040	0.00029	0.00018	0	2	-	-	-	-	-
Molybdenum	µg/L	-	73	500	-	-	0.080	-	0.080	-	-	-	0	1	-	-	-	-	-	0.15	-	0.15	-	-	-	0	1	-	-	-	-	-	0.085	0.085	0.12	0.050	0.12	0.049	0	2	-	-	-	-	-
Nickel	µg/L	309 to 1,032[b]	34 to 115[b]	1,000	-	-	0.90	-	0.90	-	-	-	0	1	-	-	-	-	-	0.30	-	0.30	-	-	-	0	1	-	-	-	-	-	0.75	0.75	0.98	0.50	1.0	0.35	0	2	-	-	-	-	-
Selenium	µg/L	-	2.0	50	50	-	<0.04	-	<0.04	-	-	-	1	1	-	-	-	-	-	<0.04	-	<0.04	-	-	-	1	1	-	-	-	-	-	0.040	-	0.040	0.040	<0.4	-	1	2	-	-	-	-	-
Silver	µg/L	-	0.25	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-	0.096	-	0.096	<0.005	0.096	-	1	2	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	110	-	110	-	-	-	0	1	-	-	-	-	-	40	-	40	-	-	-	0	1	-	-	-	-	-	75	75	89	60	90	21	0	2	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-	0.0030	-	0.0030	-	-	-	0	1	-	-	-	-	-	0.0030	-	0.0030	-	-	-	0	1	-	-	-	-	-	<0.1	-	<0.1	<0.002	<0.1	-	2	2	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	3.0	-	3.0	-	-	-	0	1	-	-	-	-	-	<0.5	-	<0.5	-	-	-	1	1	-	-	-	-	-	<5.0	-	<5.0	<0.5	<5.0	-	2	2	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-	0.16	-	0.16	-	-	-	0	1	-	-	-	-	-	0.010	-	0.010	-	-	-	0	1	-	-	-	-	-	0.040	-	0.040	0.040	<0.1	-	1	2	-	-	-	-	-
Vanadium	µg/L	-	-	100	-	-	0.40	-	0.40	-	-	-	0	1	-	-	-	-	-	<0.2	-	<0.2	-	-	-	1	1	-	-	-	-	-	1.2	-	1.2	<0.2	1.2	-	1	2	-	-	-	-	-
Zinc	µg/L	-	30	50,000	-	5,000	3.4	-	3.4	-	-	-	0	1	-	-	-	-	-	3.5	-	3.5	-	-	-	0	1	-	-	-	-	-	2.9	2.9	4.5	1.1	4.7	2.5	0	2	-	-	-	-	-
Dissolved Metals																																													
Aluminum	µg/L	100[d]	50[d]	-	-	-	24	-	24	-	-	-	0	1	-	-	-	-	-	19	-	19	-	-	-	0	1	-	-	-	-	-	12	12	12	11	12	0.71	0	2	-	-	-	-	-
Antimony	µg/L	-	-	-	-	-	0.050	-	0.050	-	-	-	0	1	-	-	-	-	-	<0.02	-	<0.02	-	-	-	1	1	-	-	-	-	-	<0.4	-	<0.4	<0.02	<0.4	-	2	2	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-	0.20	-	0.20	-	-	-	0	1	-	-	-	-	-	0.20	-	0.20	-	-	-	0	1	-	-	-	-	-	0.50	-	0.50	<0.4	0.50	-	1	2	-	-	-	-	-
Barium	µg/L	-	-	-	-	-	30	-	30	-	-	-	0	1	-	-	-	-	-	10	-	10	-	-	-	0	1	-	-	-	-	-	25	25	30	20	30	7.1	0	2	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-	<0.01	-	<0.01	-	-	-	1	1	-	-	-	-	-	<0.01	-	<0.01	-	-	-	1	1	-	-	-	-	-	<0.5	-	<0.5	<0.01	<0.5	-	2	2	-	-	-	-	-
Boron	µg/L	-	-	-	-	-	<50	-	<50	-	-	-	1	1	-	-	-	-	-	<50	-	<50	-	-	-	1	1	-	-	-	-	-	30	-	30	30	<50	-	1	2	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-	0.010	-	0.010	-	-	-	0	1	-	-	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-	<0.1	-	<0.1	<0.005	<0.1	-	2	2	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-	0.20	-	0.20	-	-	-	0	1	-	-	-	-	-	<0.1	-	<0.1	-	-	-	1	1	-	-	-	-	-	<0.4	-	<0.4	<0.1	<0.4	-	2	2	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-	0.43	-	0.43	-	-	-	0	1	-	-	-	-	-	0.060	-	0.060	-	-	-	0	1	-	-	-	-	-	0.14	-	0.14	<0.1	0.14	-	1	2	-	-	-	-	-
Copper	µg/L	-	-	-	-	-	1.0	-	1.0	-	-	-	0	1	-	-	-	-	-	0.20	-	0.20	-	-	-	0	1	-	-	-	-	-	0.20	-	0.20	0.20	<0.6	-	1	2	-	-	-	-	-
Iron	µg/L	-	300	-	-	-	**490[C]**	-	**490[C]**	-	-	-	0	1	-	100	-	-	-	160	-	160	-	-	-	0	1	-	-	-	-	-	**655[C]**	**655[C]**	**966[C]**	**310[C]**	**1,000[C]**	488	0	2	-	100	-	-	-
Lead	µg/L	-	-	-	-	-	0.15	-	0.15	-	-	-	0	1	-	-	-	-	-	0.050	-	0.050	-	-	-	0	1	-	-	-	-	-	0.020	-	0.020	0.020	<0.1	-	1	2	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	14	-	14	-	-	-	0	1	-	-	-	-	-	5.0	-	5.0	-	-	-	0	1	-	-	-	-	-	5.5	5.5	6.0	5.0	6.0	0.71	0	2	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-	280	-	280	-	-	-	0	1	-	-	-	-	-	10	-	10	-	-	-	0	1	-	-	-	-	-	52	52	83	16	87	50	0	2	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-	<0.0006	-	<0.0006	-	-	-	1	1	-	-	-	-	-	0.0010	-	0.0010	-	-	-	0	1	-	-	-	-	-	<0.0006	-	<0.0006	<0.0006	<0.0006	-	2	2	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-	0.18	-	0.18	-	-	-	0	1	-	-	-	-	-	0.070	-	0.070	-	-	-	0	1	-	-	-	-	-	<0.1	-	<0.1	<0.05	<0.1	-	2	2	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-	0.80	-	0.80	-	-	-	0	1	-	-	-	-	-	0.40	-	0.40	-	-	-	0	1	-	-	-	-	-	0.60	0.60	0.69	0.50	0.70	0.14	0	2	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-	0.050	-	0.050	-	-	-	0	1	-	-	-	-	-	<0.04	-	<0.04	-	-	-	1	1	-	-	-	-	-	<0.4	-	<0.4	<0.04	<0.4	-	2	2	-	-	-	-	-
Silver	µg/L	-	-	-	-	-	0.010	-	0.010	-	-	-	0	1	-	-	-	-	-	<0.005	-	<0.005	-	-	-	1	1	-	-	-	-	-	0.0050	-	0.0050	<0.005	0.0050	-	1	2	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	80	-	80	-	-	-	0	1	-	-	-	-	-	40	-	40	-	-	-	0	1	-	-	-	-	-	75	75	80	70	80	7.1	0	2	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-	0.0030	-	0.0030	-	-	-	0	1	-	-	-	-	-	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-	<0.05	-	<0.05	<0.002	<0.05	-	2	2	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	1.0	-	1.0	-	-	-	0	1	-	-	-	-	-	<0.5	-	<0.5	-	-	-	1	1	-	-	-	-	-	0.60	-	0.60	<0.5	0.60	-	1	2	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-	0.15	-	0.15	-	-	-	0	1	-	-	-	-	-	0.010	-	0.010	-	-	-	0	1	-	-	-	-	-	0.040	-	0.040	0.040	<0.1	-	1	2	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-	<0.2	-	<0.2	-	-	-	1	1	-	-	-	-	-	<0.2	-	<0.2	-	-	-	1	1	-	-	-	-	-	0.20	-	0.20	<0.2	0.20	-	1	2	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-	3.1	-	3.1	-	-	-	0	1	-	-	-	-	-	13	-	13	-	-	-	0	1	-	-	-	-	-	1.0	1.0	1.6	0.30	1.7	0.99	0	2	-	-	-	-	-

Table V-7: Baseline Phase Seasonal Water Quality Data from the Wapasu Creek Watershed Compared to Guidelines, 2007 to 2010

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline				
										A	C	W	D	S
Field Measured														
pH	-	7.2	-	7.2	-	-	-	0	1	-	-	-	-	-
Specific conductivity	µS/cm	213	-	213	-	-	-	0	1	-	-	-	-	-
Temperature	°C	8.1	-	8.1	-	-	-	0	1	-	-	-	-	-
Dissolved oxygen	mg/L	8.8	-	8.8	-	-	-	0	1	-	-	-	-	-
Conventional Parameters														
pH	-	8.0	8.0	8.1	7.8	8.1	0.13	0	4	-	-	-	-	-
Specific conductivity	µS/cm	217	222	244	207	247	19	0	4	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	111	114	126	105	128	10	0	4	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	111	111	123	99	124	12	0	4	-	-	-	-	-
Total dissolved solids	mg/L	184	183	198	166	199	14	0	4	-	-	-	-	-
Total suspended solids	mg/L	<3.0	-	<3.0	<3.0	<3.0	-	4	4	-	-	-	-	-
Total organic carbon	mg/L	31	30	34	24	35	4.6	0	4	-	-	-	-	-
Dissolved organic carbon	mg/L	29	25	33	11	33	9.9	0	4	-	-	-	-	-
Colour	TCU	**126**(S)	**126**(S)	**140**(S)	**110**(S)	**142**(S)	14	0	4	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	135	136	151	121	152	14	0	4	-	-	-	-	-
Calcium	mg/L	28	27	29	24	29	2.2	0	4	-	-	-	-	-
Carbonate	mg/L	<5.0	-	<5.0	<5.0	<5.0	-	4	4	-	-	-	-	-
Chloride	mg/L	2.0	2.0	2.9	1.0	3.0	0.82	0	4	-	-	-	-	-
Magnesium	mg/L	9.3	9.6	11	8.6	11	1.0	0	4	-	-	-	-	-
Potassium	mg/L	1.0	-	1.6	<0.5	1.7	-	2	4	-	-	-	-	-
Sodium	mg/L	7.0	7.0	7.9	6.0	8.0	0.82	0	4	-	-	-	-	-
Sulphate	mg/L	2.0	2.3	2.9	2.0	3.0	0.50	0	4	-	-	-	-	-
Sulphide	mg/L	**0.015**(C)	**0.015**(C)	**0.019**(C)	0.011	**0.019**(C)	0.0041	0	4	-	50	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.1	-	<0.1	<0.071	<0.1	-	4	4	-	-	-	-	-
Total ammonia	mg-N/L	<0.05	-	<0.05	<0.05	<0.05	-	4	4	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	1.2	1.2	1.7	0.80	1.8	0.43	0	4	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	1.2	1.2	1.7	0.80	1.8	0.43	0	4	-	-	-	-	-
Total phosphorus	mg-P/L	0.020	0.014	0.020	0.0020	0.020	0.010	0	3	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.011	0.012	0.015	0.0090	0.015	0.0031	0	3	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	<2.0	<2.0	<2.0	-	4	4	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	0.20	-	<1.0	0.10	<1.0	-	2	4	-	-	-	-	-
Phenol(f)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics(g)	mg/L	**0.0090**(C, W)	**0.0098**(C, W)	**0.014**(C, W)	**0.0060**(C, W)	**0.015**(C, W)	0.0038	0	4	-	100	100	-	-
Total recoverable hydrocarbons	mg/L	<1.0	-	<1.0	<1.0	<1.0	-	4	4	-	-	-	-	-
Total Metals														
Aluminum	µg/L	20	30	63	10	70	27	0	4	-	-	-	-	-
Antimony	µg/L	0.020	-	0.020	0.020	<0.05	-	1	4	-	-	-	-	-
Arsenic	µg/L	0.35	0.38	0.49	0.30	0.50	0.096	0	4	-	-	-	-	-
Barium	µg/L	20	20	20	20	20	0	0	4	-	-	-	-	-
Beryllium	µg/L	0.010	-	0.010	<0.01	<0.1	-	3	4	-	-	-	-	-
Boron	µg/L	20	23	29	20	30	5.0	0	4	-	-	-	-	-
Cadmium	µg/L	<0.006	-	<0.1	0.0030	<0.1	-	3	4	-	-	-	-	-
Chromium	µg/L	<0.3	-	<0.3	0.080	<0.3	-	3	4	-	-	-	-	-
Cobalt	µg/L	0.070	-	0.11	0.050	0.11	-	1	4	-	-	-	-	-
Copper	µg/L	0.10	0.25	0.61	0.10	0.70	0.30	0	4	-	-	-	-	-
Iron	µg/L	250	300	**470**(S)	200	**500**(S)	141	0	4	-	-	-	-	25
Lead	µg/L	0.020	-	0.030	<0.006	<0.1	-	2	4	-	-	-	-	-
Lithium	µg/L	5.0	6.3	10	4.0	11	3.2	0	4	-	-	-	-	-
Manganese	µg/L	20	25	47	10	50	19	0	4	-	-	-	-	-
Mercury	µg/L	0.0030	-	0.0030	0.0010	<0.05(DL>A, DL>C)	-	2	4	-	-	-	-	-
Methyl mercury	µg/L	-	-	-	-	-	-	0	0	-	-	-	-	-
Molybdenum	µg/L	0.045	-	0.050	0.040	<0.1	-	1	4	-	-	-	-	-
Nickel	µg/L	0.10	-	0.19	<0.06	0.20	-	2	4	-	-	-	-	-
Selenium	µg/L	<0.3	-	<0.3	0.18	<0.3	-	3	4	-	-	-	-	-
Silver	µg/L	<0.005	-	<0.01	0.0021	<0.01	-	3	4	-	-	-	-	-
Strontium	µg/L	75	73	80	60	80	9.6	0	4	-	-	-	-	-
Thallium	µg/L	0.0030	-	0.0030	<0.003	<0.1	-	3	4	-	-	-	-	-
Titanium	µg/L	2.0	1.8	2.0	1.0	2.0	0.50	0	4	-	-	-	-	-
Uranium	µg/L	0.020	-	0.030	0.010	<0.1	-	1	4	-	-	-	-	-
Vanadium	µg/L	0.15	0.15	0.20	0.10	0.20	0.058	0	4	-	-	-	-	-
Zinc	µg/L	0.95	0.93	1.2	0.60	1.2	0.28	0	4	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	7.0	6.8	8.9	4.0	9.0	2.2	0	4	-	-	-	-	-
Antimony	µg/L	0.020	-	0.020	0.020	<0.05	-	1	4	-	-	-	-	-
Arsenic	µg/L	0.30	0.35	0.47	0.30	0.50	0.10	0	4	-	-	-	-	-
Barium	µg/L	20	20	20	20	20	0	0	4	-	-	-	-	-
Beryllium	µg/L	<0.01	-	<0.1	0.0040	<0.1	-	3	4	-	-	-	-	-
Boron	µg/L	20	23	29	20	30	5.0	0	4	-	-	-	-	-
Cadmium	µg/L	<0.006	-	<0.1	0.0020	<0.1	-	3	4	-	-	-	-	-
Chromium	µg/L	<0.3	-	<0.3	0.10	<0.3	-	3	4	-	-	-	-	-
Cobalt	µg/L	0.055	-	0.060	0.040	<0.1	-	1	4	-	-	-	-	-
Copper	µg/L	0.10	0.25	0.61	0.10	0.70	0.30	0	4	-	-	-	-	-
Iron	µg/L	180	183	253	110	260	66	0	4	-	-	-	-	-
Lead	µg/L	0.010	-	0.010	<0.006	<0.1	-	3	4	-	-	-	-	-
Lithium	µg/L	5.0	6.3	10	4.0	11	3.2	0	4	-	-	-	-	-
Manganese	µg/L	2.5	2.8	3.9	2.0	4.0	0.96	0	4	-	-	-	-	-
Mercury	µg/L	<0.05	-	<0.05	<0.05	<0.05	-	4	4	-	-	-	-	-
Molybdenum	µg/L	0.050	-	0.050	0.040	<0.1	-	1	4	-	-	-	-	-
Nickel	µg/L	<0.1	-	0.20	<0.06	0.20	-	3	4	-	-	-	-	-
Selenium	µg/L	<0.3	-	<0.3	0.18	<0.3	-	3	4	-	-	-	-	-
Silver	µg/L	<0.005	-	<0.01	<0.005	<0.01	-	4	4	-	-	-	-	-
Strontium	µg/L	75	73	80	60	80	9.6	0	4	-	-	-	-	-
Thallium	µg/L	0.0030	-	0.0030	<0.003	<0.1	-	3	4	-	-	-	-	-
Titanium	µg/L	1.2	1.2	1.5	0.80	1.5	0.29	0	4	-	-	-	-	-
Uranium	µg/L	0.020	-	0.030	0.010	<0.1	-	1	4	-	-	-	-	-
Vanadium	µg/L	0.10	0.10	0.10	0.10	0.10	0	0	4	-	-	-	-	-
Zinc	µg/L	0.95	0.93	1.2	0.60	1.2	0.28	0	4	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (61 to 254 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (6.9 to 8.1). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The minimum ammonia guideline (0.79 mg-N/L) is presented and was calculated based on the combination of field pH (8.1) and water temperature (8.1°C). The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
DL>A = Analytical detection limit is higher than the acute aquatic life GOA (2018) guideline.
DL>C = Analytical detection limit is higher than the chronic aquatic life GOA (2018) guideline.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.

- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; > = greater than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit.

Table V-8: Operational Phase Seasonal Water Quality Data from the Wapasu Creek Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	GOA (2018) Guidelines for the Protection of: Aquatic Life – Acute	Aquatic Life – Chronic	Wildlife Health (Livestock)	Health Canada (2017) Drinking Water MAC	Drinking Water AO	Seasonal Summary – Winter: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.3	7.4	7.8	7.0	7.9	0.31	0	7	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	540	507	567	407	572	61	0	7	-	-	-	-	-
Temperature	°C	-	-	-	-	15	0.14	0.32	0.85	-0.1	1.0	0.37	0	7	-	-	-	-	-
Dissolved oxygen	mg/L	5.0	6.5	-	-	-	**6.2[(C)]**	7.5	11	**3.6[(A, C)]**	11	3.3	0	7	29	57	-	-	-
Conventional Parameters																			
pH	-	-	6.5 to 9.0	-	-	7.0 to 11	7.9	7.9	8.1	7.6	8.1	0.17	0	7	-	-	-	-	-
Specific conductivity	µS/cm	-	-	-	-	-	570	539	580	400	580	64	0	7	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	-	-	-	-	-	300	280	313	183	314	46	0	7	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	-	20[(a)]	-	-	-	290	281	314	210	320	35	0	7	-	-	-	-	-
Total dissolved solids	mg/L	-	-	3,000	-	500	330	317	330	270	330	22	0	7	-	-	-	-	-
Total suspended solids	mg/L	-	-	-	-	-	1.7	-	6.8	<1.0	8.0	-	3	7	-	-	-	-	-
Total organic carbon	mg/L	-	-	-	-	-	11	14	24	8.1	28	7.0	0	7	-	-	-	-	-
Dissolved organic carbon	mg/L	-	-	-	-	-	9.4	13	24	7.3	27	7.0	0	7	-	-	-	-	-
Colour	TCU	-	-	-	-	15	**27[(S)]**	**36[(S)]**	**79[(S)]**	14	**92[(S)]**	27	0	7	-	-	-	-	71
Major Ions																			
Bicarbonate	mg/L	-	-	-	-	-	350	341	381	250	390	44	0	7	-	-	-	-	-
Calcium	mg/L	-	-	1,000	-	-	76	73	83	50	84	11	0	7	-	-	-	-	-
Carbonate	mg/L	-	-	-	-	-	<0.5	-	<1.0	<0.5	<1.0	-	7	7	-	-	-	-	-
Chloride	mg/L	640	120	-	-	250	4.0	4.1	6.5	1.7	7.0	1.8	0	7	-	-	-	-	-
Magnesium	mg/L	-	-	-	-	-	25	25	28	18	28	3.5	0	7	-	-	-	-	-
Potassium	mg/L	-	-	-	-	-	1.5	1.6	1.7	1.5	1.8	0.11	0	7	-	-	-	-	-
Sodium	mg/L	-	-	-	-	200	8.6	8.7	10	7.2	11	1.2	0	7	-	-	-	-	-
Sulphate	mg/L	-	218 to 429[(b, c)]	1,000	-	500	<1.0	-	3.8	<1.0	4.1	-	4	7	-	-	-	-	-
Sulphide	mg/L	-	0.0021 to 0.019[(d)]	-	-	0.050	<0.002	-	0.0094	<0.0019	0.010	-	4	7	-	29	-	-	-
Nutrients and Biological Indicators																			
Nitrate + nitrite	mg-N/L	-	-	100	-	-	0.017	0.016	0.031	0.0060	0.034	0.011	1	7	-	-	-	-	-
Total ammonia	mg-N/L	-	0.45[(e)]	-	-	-	0.36	0.39	0.63	0.17	0.67	0.19	0	7	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	-	-	-	-	-	0.90	0.86	1.3	0.33	1.3	0.37	0	7	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	-	-	-	-	-	0.91	0.88	1.3	0.36	1.3	0.37	0	7	-	-	-	-	-
Total phosphorus	mg-P/L	-	-	-	-	-	0.036	0.035	0.057	0.015	0.060	0.019	0	7	-	-	-	-	-
Dissolved phosphorus	mg-P/L	-	-	-	-	-	0.0060	-	0.050	<0.001	0.059	-	3	7	-	-	-	-	-
Biochemical oxygen demand	mg/L	-	-	-	-	-	<2.0	-	2.7	<2.0	2.8	-	4	7	-	-	-	-	-
General Organics																			
Naphthenic acids	mg/L	-	-	-	-	-	<1.0	-	<1.0	<1.0	<1.0	-	7	7	-	-	-	-	-
Phenol[(f)]	mg/L	-	0.0040	0.0020	-	-	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-
Total phenolics[(g)]	mg/L	-	0.0040	0.0020	-	-	**0.0029[(W)]**	-	**0.0068[(C, W)]**	<0.002	**0.0070[(C, W)]**	-	2	6	-	33	67	-	-
Total recoverable hydrocarbons	mg/L	-	-	-	-	-	<2.0	-	2.5	<2.0	2.5	-	6	7	-	-	-	-	-
Total Metals																			
Aluminum	µg/L	-	-	5,000	-	-	10	18	41	4.3	46	15	0	7	-	-	-	-	-
Antimony	µg/L	-	-	-	6.0	-	0.026	-	0.087	<0.02	0.11	-	2	7	-	-	-	-	-
Arsenic	µg/L	-	5.0	25	10	-	0.20	0.21	0.38	0.097	0.40	0.12	0	7	-	-	-	-	-
Barium	µg/L	-	-	-	1,000	-	65	63	75	40	78	12	0	7	-	-	-	-	-
Beryllium	µg/L	-	-	100	-	-	<0.01	-	<0.01	<0.01	<0.01	-	7	7	-	-	-	-	-
Boron	µg/L	29,000	1,500	5,000	5,000	-	<50	-	<50	33	<50	-	4	7	-	-	-	-	-
Cadmium	µg/L	1.5 to 6.7[(b)]	0.12 to 0.37[(b)]	80	5.0	-	<0.005	-	0.067	<0.005	0.085	-	4	7	-	-	-	-	-
Chromium	µg/L	-	1.0[(h)]	50	50[(h)]	-	0.13	0.17	0.33	0.10	0.40	0.10	0	7	-	-	-	-	-
Cobalt	µg/L	-	0.90 to 1.6[(b)]	1,000	-	-	0.38	0.49	0.98	0.21	1.2	0.32	0	7	-	-	-	-	-
Copper	µg/L	12 to 49[(b)]	7.0[(b)]	500	-	1,000	0.30	0.28	0.50	0.10	0.54	0.16	0	7	-	-	-	-	-
Iron	µg/L	-	-	-	-	300	**1,970[(S)]**	**1,936[(S)]**	**3,308[(S)]**	**839[(S)]**	**3,440[(S)]**	990	0	7	-	-	-	-	100
Lead	µg/L	-	2.1 to 7.0[(b)]	100	10	-	0.050	0.23	0.97	0.0065	1.4	0.50	0	7	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	9.8	10.0	12	8.9	12	1.2	0	7	-	-	-	-	-
Manganese	µg/L	-	-	-	-	50	**888[(S)]**	**924[(S)]**	**1,714[(S)]**	**390[(S)]**	**2,020[(S)]**	540	0	7	-	-	-	-	100
Mercury	µg/L	0.013	0.0050	3.0	1.0	-	<0.0006	0.00069	0.0011	0.00034	0.0011	0.00034	1	7	-	-	-	-	-
Methyl mercury	µg/L	0.0020	0.0010	-	-	-	0.00015	0.00019	0.00034	0.000090	0.00035	0.000097	0	7	-	-	-	-	-
Molybdenum	µg/L	-	73	500	-	-	<0.05	-	0.055	<0.05	0.057	-	5	7	-	-	-	-	-
Nickel	µg/L	360 to 1,235[(b)]	40 to 137[(b)]	1,000	-	-	0.33	0.39	0.56	0.23	0.58	0.13	0	7	-	-	-	-	-
Selenium	µg/L	-	2.0	50	50	-	<0.04	-	0.060	<0.04	0.060	-	6	7	-	-	-	-	-
Silver	µg/L	-	0.25	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	7	7	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	128	127	136	120	139	6.8	0	7	-	-	-	-	-
Thallium	µg/L	-	0.80	-	-	-	<0.002	-	0.0026	<0.002	0.0026	-	6	7	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	<0.5	-	1.1	<0.5	1.1	-	5	7	-	-	-	-	-
Uranium	µg/L	33	15	200	20	-	0.15	0.15	0.22	0.060	0.23	0.053	0	7	-	-	-	-	-
Vanadium	µg/L	-	-	100	-	-	<0.2	-	0.20	<0.2	0.20	-	6	7	-	-	-	-	-
Zinc	µg/L	-	30	50,000	-	5,000	4.0	3.7	6.1	1.4	6.3	2.2	0	7	-	-	-	-	-
Dissolved Metals																			
Aluminum	µg/L	70 to 100[(d)]	36 to 50[(d)]	-	-	-	3.2	3.5	8.2	1.0	10	3.1	0	7	-	-	-	-	-
Antimony	µg/L	-	-	-	-	-	<0.02	-	0.055	<0.02	0.070	-	5	7	-	-	-	-	-
Arsenic	µg/L	-	-	-	-	-	0.11	0.16	0.27	0.096	0.30	0.078	0	7	-	-	-	-	-
Barium	µg/L	-	-	-	-	-	60	58	63	40	63	8.1	0	7	-	-	-	-	-
Beryllium	µg/L	-	-	-	-	-	<0.01	-	<0.01	<0.01	<0.01	-	7	7	-	-	-	-	-
Boron	µg/L	-	-	-	-	-	<50	-	<50	28	<50	-	4	7	-	-	-	-	-
Cadmium	µg/L	-	-	-	-	-	<0.005	-	0.076	<0.005	0.098	-	4	7	-	-	-	-	-
Chromium	µg/L	-	-	-	-	-	<0.1	-	0.10	<0.1	0.10	-	6	7	-	-	-	-	-
Cobalt	µg/L	-	-	-	-	-	0.37	0.41	0.67	0.20	0.74	0.19	0	7	-	-	-	-	-
Copper	µg/L	-	-	-	-	-	0.084	-	3.8	<0.05	5.2	-	2	7	-	-	-	-	-
Iron	µg/L	-	300	-	-	-	52	**463[(C)]**	**1,575[(C)]**	30	**2,000[(C)]**	716	0	7	-	43	-	-	-
Lead	µg/L	-	-	-	-	-	<0.005	-	1.5	<0.005	2.1	-	4	7	-	-	-	-	-
Lithium	µg/L	-	-	-	-	-	9.5	10	13	9.0	14	1.8	0	7	-	-	-	-	-
Manganese	µg/L	-	-	-	-	-	580	719	1,332	360	1,520	395	0	7	-	-	-	-	-
Mercury	µg/L	-	-	-	-	-	0.00041	-	0.0010	0.00014	0.0010	-	2	6	-	-	-	-	-
Molybdenum	µg/L	-	-	-	-	-	<0.05	-	0.11	<0.05	0.11	-	6	7	-	-	-	-	-
Nickel	µg/L	-	-	-	-	-	0.33	0.32	0.47	0.20	0.50	0.11	0	7	-	-	-	-	-
Selenium	µg/L	-	-	-	-	-	<0.04	-	0.047	<0.04	0.050	-	5	7	-	-	-	-	-
Silver	µg/L	-	-	-	-	-	<0.005	-	<0.005	<0.005	<0.005	-	7	7	-	-	-	-	-
Strontium	µg/L	-	-	-	-	-	120	123	132	115	132	6.4	0	7	-	-	-	-	-
Thallium	µg/L	-	-	-	-	-	<0.002	-	0.0036	<0.002	0.0043	-	5	7	-	-	-	-	-
Titanium	µg/L	-	-	-	-	-	<0.5	-	<0.5	<0.5	<0.5	-	7	7	-	-	-	-	-
Uranium	µg/L	-	-	-	-	-	0.15	0.14	0.20	0.050	0.21	0.052	0	7	-	-	-	-	-
Vanadium	µg/L	-	-	-	-	-	<0.2	-	<0.2	<0.2	<0.2	-	7	7	-	-	-	-	-
Zinc	µg/L	-	-	-	-	-	0.91	2.4	5.4	0.42	5.5	2.3	0	7	-	-	-	-	-

Parameter	Seasonal Summary – Spring: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.2	7.2	7.5	**6.8[(S)]**	7.6	0.29	0	7	-	-	-	-	29
Specific conductivity	202	229	391	159	453	104	0	7	-	-	-	-	-
Temperature	5.0	5.6	14	-3.2	**16[(S)]**	6.8	0	7	-	-	-	-	14
Dissolved oxygen	10	10	12	8.0	12	1.6	0	7	-	-	-	-	-
Conventional Parameters													
pH	7.9	7.8	8.0	7.5	8.1	0.18	0	8	-	-	-	-	-
Specific conductivity	200	223	325	160	360	63	0	8	-	-	-	-	-
Hardness, as $CaCO_3$	90	104	161	73	178	36	0	8	-	-	-	-	-
Total alkalinity, as $CaCO_3$	82	99	166	65	180	40	0	8	-	-	-	-	-
Total dissolved solids	145	156	222	120	250	42	0	8	-	-	-	-	-
Total suspended solids	1.9	-	4.0	<1.0	4.0	-	2	8	-	-	-	-	-
Total organic carbon	18	18	23	13	24	3.2	0	8	-	-	-	-	-
Dissolved organic carbon	18	18	22	13	24	3.1	0	8	-	-	-	-	-
Colour	**62[(S)]**	**63[(S)]**	**84[(S)]**	**35[(S)]**	**86[(S)]**	19	0	8	-	-	-	-	100
Major Ions													
Bicarbonate	102	121	203	79	220	49	0	8	-	-	-	-	-
Calcium	23	27	44	18	50	11	0	8	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	8	8	-	-	-	-	-
Chloride	7.3	6.8	11	3.0	12	2.9	0	8	-	-	-	-	-
Magnesium	7.7	9.0	14	6.4	16	3.2	0	8	-	-	-	-	-
Potassium	1.9	2.0	3.0	1.2	3.4	0.67	0	8	-	-	-	-	-
Sodium	7.0	7.1	9.3	5.0	10	1.6	0	8	-	-	-	-	-
Sulphate	4.0	-	14	<1.0	17	-	2	8	-	-	-	-	-
Sulphide	0.0035	-	**0.0083[(C)]**	<0.0019	**0.0090[(C)]**	-	3	8	-	38	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.01	-	0.099	<0.003	0.13	-	5	8	-	-	-	-	-
Total ammonia	<0.05	-	0.53	<0.015	0.54	-	4	8	-	-	-	-	-
Total Kjeldahl nitrogen	0.66	0.73	1.0	0.50	1.1	0.21	0	8	-	-	-	-	-
Total nitrogen (calculated)	0.66	0.75	1.1	0.50	1.1	0.24	0	8	-	-	-	-	-
Total phosphorus	0.015	0.028	0.078	0.0083	0.090	0.029	0	8	-	-	-	-	-
Dissolved phosphorus	0.010	0.11	0.55	0.0060	0.82	0.29	0	8	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	2.6	<2.0	2.6	-	6	8	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	8	8	-	-	-	-	-
Phenol[(f)]	**0.0033[(W)]**	-	**0.0049[(C, W)]**	<0.002	**0.0051[(C, W)]**	-	1	3	-	33	67	-	-
Total phenolics[(g)]	**0.0035[(W)]**	**0.0039[(W)]**	**0.0056[(C, W)]**	**0.0030[(W)]**	**0.0060[(C, W)]**	0.0012	0	5	-	20	100	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	8	8	-	-	-	-	-
Total Metals													
Aluminum	24	23	33	7.8	34	9.1	0	8	-	-	-	-	-
Antimony	0.020	-	0.065	<0.02	0.080	-	4	8	-	-	-	-	-
Arsenic	0.20	0.23	0.34	0.20	0.40	0.069	0	8	-	-	-	-	-
Barium	20	22	36	15	40	8.4	0	8	-	-	-	-	-
Beryllium	<0.01	-	<0.01	<0.01	<0.01	-	8	8	-	-	-	-	-
Boron	27	-	<50	16	<50	-	3	8	-	-	-	-	-
Cadmium	0.0050	-	0.023	<0.005	0.025	-	4	8	-	-	-	-	-
Chromium	<0.1	-	0.16	<0.1	0.19	-	6	8	-	-	-	-	-
Cobalt	0.078	0.17	0.48	0.067	0.52	0.18	0	8	-	-	-	-	-
Copper	0.20	-	0.76	0.053	1.0	-	2	8	-	-	-	-	-
Iron	255	**832[(S)]**	**2,755[(S)]**	170	**3,000[(S)]**	1,139	0	8	-	-	-	-	25
Lead	0.039	0.071	0.19	0.016	0.19	0.073	1	8	-	-	-	-	-
Lithium	6.6	6.8	9.0	5.0	9.6	1.4	0	8	-	-	-	-	-
Manganese	22	**213[(S)]**	**853[(S)]**	15	**1,000[(S)]**	373	0	8	-	-	-	-	25
Mercury	0.0010	-	0.0015	<0.0006	0.0016	-	2	8	-	-	-	-	-
Methyl mercury	0.00012	0.00015	0.00028	0.000070	0.00030	0.000091	1	8	-	-	-	-	-
Molybdenum	0.074	0.069	0.091	<0.05	0.092	0.022	1	8	-	-	-	-	-
Nickel	0.40	0.70	1.8	0.34	2.2	0.65	0	8	-	-	-	-	-
Selenium	<0.04	-	<0.04	<0.04	<0.04	-	8	8	-	-	-	-	-
Silver	<0.005	-	<0.01	<0.005	<0.01	-	8	8	-	-	-	-	-
Strontium	57	66	98	50	110	20	0	8	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	7	8	-	-	-	-	-
Titanium	1.0	-	3.5	<0.5	4.0	-	2	8	-	-	-	-	-
Uranium	0.010	0.017	0.043	0.0079	0.050	0.015	0	8	-	-	-	-	-
Vanadium	<0.2	-	<0.2	<0.2	<0.2	-	8	8	-	-	-	-	-
Zinc	2.0	-	14	<1.0	17	-	2	8	-	-	-	-	-
Dissolved Metals													
Aluminum	6.0	7.6	16	3.0	17	5.1	0	8	-	-	-	-	-
Antimony	<0.02	-	0.041	<0.02	0.050	-	5	8	-	-	-	-	-
Arsenic	0.22	0.22	0.28	0.16	0.30	0.044	0	8	-	-	-	-	-
Barium	20	22	37	13	40	9.0	0	8	-	-	-	-	-
Beryllium	<0.01	-	<0.01	<0.01	<0.01	-	8	8	-	-	-	-	-
Boron	28	-	<50	17	<50	-	4	8	-	-	-	-	-
Cadmium	<0.005	-	0.011	<0.005	0.013	-	6	8	-	-	-	-	-
Chromium	<0.1	-	0.20	<0.1	0.20	-	7	8	-	-	-	-	-
Cobalt	0.054	0.15	0.47	0.035	0.50	0.19	0	8	-	-	-	-	-
Copper	0.14	-	1.8	<0.05	2.4	-	2	8	-	-	-	-	-
Iron	130	**634[(C)]**	**2,260[(C)]**	66	**2,400[(C)]**	973	0	8	-	25	-	-	-
Lead	0.020	-	0.095	<0.005	0.13	-	4	8	-	-	-	-	-
Lithium	6.8	6.9	8.9	5.0	9.3	1.5	0	8	-	-	-	-	-
Manganese	5.3	153	603	0.58	610	276	0	8	-	-	-	-	-
Mercury	0.00073	-	0.0010	0.00052	0.0010	-	3	8	-	-	-	-	-
Molybdenum	0.068	0.077	0.13	<0.05	0.15	0.037	1	8	-	-	-	-	-
Nickel	0.39	0.41	0.67	0.21	0.70	0.16	0	8	-	-	-	-	-
Selenium	<0.04	-	0.050	<0.04	0.050	-	7	8	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	8	8	-	-	-	-	-
Strontium	62	66	98	47	110	20	0	8	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	7	8	-	-	-	-	-
Titanium	<0.5	-	<0.5	<0.5	<0.5	-	8	8	-	-	-	-	-
Uranium	0.0090	0.016	0.041	0.0064	0.050	0.015	0	8	-	-	-	-	-
Vanadium	<0.2	-	<0.2	<0.2	<0.2	-	8	8	-	-	-	-	-
Zinc	0.95	1.8	5.4	0.19	6.1	2.2	0	8	-	-	-	-	-

Parameter	Seasonal Summary – Summer: Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured													
pH	7.2	7.2	7.8	**6.4[(C, S)]**	7.9	0.52	0	6	-	17	-	-	17
Specific conductivity	364	328	463	170	499	111	0	7	-	-	-	-	-
Temperature	**16[(S)]**	**15[(S)]**	**18[(S)]**	12	**19[(S)]**	2.4	0	7	-	-	-	-	71
Dissolved oxygen	6.9	**5.4[(C)]**	8.2	**1.5[(A, C)]**	8.6	2.8	0	7	43	43	-	-	-
Conventional Parameters													
pH	8.0	8.0	8.1	7.8	8.1	0.14	0	7	-	-	-	-	-
Specific conductivity	380	379	507	260	510	103	0	7	-	-	-	-	-
Hardness, as $CaCO_3$	191	202	280	133	280	62	0	7	-	-	-	-	-
Total alkalinity, as $CaCO_3$	210	197	260	130	260	56	0	7	-	-	-	-	-
Total dissolved solids	250	244	291	200	300	36	0	7	-	-	-	-	-
Total suspended solids	1.0	-	3.8	<1.0	4.8	-	3	7	-	-	-	-	-
Total organic carbon	24	24	34	14	37	7.2	0	7	-	-	-	-	-
Dissolved organic carbon	24	24	34	14	37	7.4	0	7	-	-	-	-	-
Colour	**83[(S)]**	**75[(S)]**	**121[(S)]**	**17[(S)]**	**130[(S)]**	39	0	7	-	-	-	-	100
Major Ions													
Bicarbonate	260	240	320	160	320	70	0	7	-	-	-	-	-
Calcium	52	52	71	35	72	15	0	7	-	-	-	-	-
Carbonate	<0.5	-	<1.0	<0.5	<1.0	-	7	7	-	-	-	-	-
Chloride	6.0	5.1	6.7	2.0	6.8	1.7	0	7	-	-	-	-	-
Magnesium	15	17	24	11	24	5.3	0	7	-	-	-	-	-
Potassium	0.89	0.92	1.4	0.29	1.4	0.37	0	7	-	-	-	-	-
Sodium	8.2	8.0	9.2	6.0	9.2	1.2	0	7	-	-	-	-	-
Sulphate	<1.0	-	<1.0	<1.0	<1.0	-	7	7	-	-	-	-	-
Sulphide	**0.0080[(C)]**	**0.0082[(C)]**	**0.015[(C)]**	<0.002	**0.016[(C)]**	0.0047	1	7	-	43	-	-	-
Nutrients and Biological Indicators													
Nitrate + nitrite	<0.014	-	0.024	<0.003	0.024	-	4	7	-	-	-	-	-
Total ammonia	<0.05	-	0.075	0.016	0.086	-	3	7	-	-	-	-	-
Total Kjeldahl nitrogen	0.89	0.91	1.5	0.43	1.7	0.41	0	7	-	-	-	-	-
Total nitrogen (calculated)	0.89	0.92	1.5	0.43	1.7	0.42	0	7	-	-	-	-	-
Total phosphorus	0.030	0.026	0.037	0.014	0.040	0.0092	0	7	-	-	-	-	-
Dissolved phosphorus	0.018	0.016	0.028	0.0048	0.030	0.0090	0	7	-	-	-	-	-
Biochemical oxygen demand	<2.0	-	<2.0	<2.0	<2.0	-	7	7	-	-	-	-	-
General Organics													
Naphthenic acids	<1.0	-	<1.0	<1.0	<1.0	-	7	7	-	-	-	-	-
Phenol[(f)]	**0.0051[(C, W)]**	-	**0.0051[(C, W)]**	<0.002	**0.0051[(C, W)]**	-	1	2	-	50	50	-	-
Total phenolics[(g)]	**0.0040[(W)]**	-	**0.0076[(C, W)]**	<0.002	**0.0080[(C, W)]**	-	2	5	-	40	60	-	-
Total recoverable hydrocarbons	<2.0	-	<2.0	<2.0	<2.0	-	7	7	-	-	-	-	-
Total Metals													
Aluminum	26	21	37	3.8	40	14	0	7	-	-	-	-	-
Antimony	0.020	-	0.022	<0.02	<0.05	-	4	7	-	-	-	-	-
Arsenic	0.47	0.42	0.57	0.20	0.60	0.14	0	7	-	-	-	-	-
Barium	38	37	46	30	48	6.9	0	7	-	-	-	-	-
Beryllium	<0.01	-	0.011	<0.01	0.011	-	5	7	-	-	-	-	-
Boron	<50	-	<50	24	<50	-	4	7	-	-	-	-	-
Cadmium	<0.005	-	0.011	<0.005	0.013	-	5	7	-	-	-	-	-
Chromium	0.11	-	0.20	<0.1	<0.5	-	4	7	-	-	-	-	-
Cobalt	0.18	0.19	0.23	0.11	0.23	0.042	0	7	-	-	-	-	-
Copper	0.10	0.37	1.2	0.056	1.4	0.50	1	7	-	-	-	-	-
Iron	**762[(S)]**	**739[(S)]**	**1,000[(S)]**	**320[(S)]**	**1,000[(S)]**	298	0	7	-	-	-	-	100
Lead	0.040	-	0.067	0.0087	0.070	-	2	7	-	-	-	-	-
Lithium	8.0	8.3	9.3	7.7	9.4	0.60	0	7	-	-	-	-	-
Manganese	**108[(S)]**	**124[(S)]**	**191[(S)]**	**60[(S)]**	**200[(S)]**	53	0	7	-	-	-	-	100
Mercury	0.00092	0.00086	0.0014	0.00058	0.0016	0.00040	1	7	-	-	-	-	-
Methyl mercury	0.00018	0.00025	0.00049	<0.00003	0.00052	0.00019	1	7	-	-	-	-	-
Molybdenum	0.060	-	0.093	<0.05	0.10	-	3	7	-	-	-	-	-
Nickel	0.50	0.52	0.76	0.25	0.78	0.19	0	7	-	-	-	-	-
Selenium	0.041	-	0.050	<0.04	0.050	-	3	7	-	-	-	-	-
Silver	<0.005	-	0.040	<0.005	0.040	-	6	7	-	-	-	-	-
Strontium	110	113	130	100	130	14	0	7	-	-	-	-	-
Thallium	<0.002	-	0.0020	<0.002	0.0020	-	5	7	-	-	-	-	-
Titanium	1.0	-	<5.0	<0.5	<5.0	-	5	7	-	-	-	-	-
Uranium	0.055	0.067	0.14	0.020	0.14	0.050	0	7	-	-	-	-	-
Vanadium	<0.2	-	<0.5	<0.2	<0.5	-	7	7	-	-	-	-	-
Zinc	1.0	-	3.5	0.31	4.0	-	2	7	-	-	-	-	-
Dissolved Metals													
Aluminum	6.2	6.1	9.6	1.2	9.8	3.0	0	7	-	-	-	-	-
Antimony	<0.02	-	0.053	<0.02	0.063	-	4	7	-	-	-	-	-
Arsenic	0.40	0.38	0.55	0.19	0.60	0.13	0	7	-	-	-	-	-
Barium	34	35	47	20	47	9.8	0	7	-	-	-	-	-
Beryllium	<0.01	-	0.023	<0.01	0.023	-	6	7	-	-	-	-	-
Boron	37	-	<50	14	<50	-	3	7	-	-	-	-	-
Cadmium	<0.005	-	<0.005	<0.005	<0.005	-	7	7	-	-	-	-	-
Chromium	<0.1	-	0.10	<0.1	0.10	-	6	7	-	-	-	-	-
Cobalt	0.12	0.13	0.17	0.090	0.18	0.033	0	7	-	-	-	-	-
Copper	0.056	-	0.10	<0.05	0.10	-	2	7	-	-	-	-	-
Iron	**310[(C)]**	**384[(C)]**	**847[(C)]**	54	**1,000[(C)]**	316	0	7	-	57	-	-	-
Lead	0.0061	-	0.034	<0.005	0.040	-	3	7	-	-	-	-	-
Lithium	8.1	8.5	9.3	8.0	9.3	0.61	0	7	-	-	-	-	-
Manganese	29	48	103	3.1	110	39	0	7	-	-	-	-	-
Mercury	0.00073	0.00100	0.0020	0.00034	0.0020	0.00075	1	7	-	-	-	-	-
Molybdenum	<0.05	-	0.088	<0.05	0.10	-	4	7	-	-	-	-	-
Nickel	0.40	0.48	0.81	0.29	0.90	0.21	0	7	-	-	-	-	-
Selenium	<0.04	-	0.057	<0.04	0.060	-	5	7	-	-	-	-	-
Silver	<0.005	-	<0.005	<0.005	<0.005	-	7	7	-	-	-	-	-
Strontium	117	115	144	90	150	21	0	7	-	-	-	-	-
Thallium	<0.002	-	<0.002	<0.002	<0.002	-	7	7	-	-	-	-	-
Titanium	<0.5	-	<0.5	<0.5	<0.5	-	7	7	-	-	-	-	-
Uranium	0.052	0.063	0.14	0.010	0.14	0.056	0	7	-	-	-	-	-
Vanadium	<0.2	-	<0.2	<0.2	<0.2	-	7	7	-	-	-	-	-
Zinc	0.29	1.1	3.5	0.17	4.3	1.5	0	7	-	-	-	-	-

Table V-8: Operational Phase Seasonal Water Quality Data from the Wapasu Creek Watershed Compared to Guidelines, 2011 to 2018

Parameter	Unit	Seasonal Summary												
		Fall												
		Median	Mean	95th Percentile	Minimum	Maximum	Standard Deviation	nd	Count	% Above Guideline A	C	W	D	S
Field Measured														
pH	-	7.2	7.2	7.3	7.0	7.3	0.21	0	2	-	-	-	-	-
Specific conductivity	µS/cm	272	272	273	271	273	1.4	0	2	-	-	-	-	-
Temperature	°C	6.1	6.1	11	1.0	11	7.1	0	2	-	-	-	-	-
Dissolved oxygen	mg/L	11	11	12	9.4	12	1.6	0	2	-	-	-	-	-
Conventional Parameters														
pH	-	7.9	7.9	8.2	7.7	8.2	0.17	0	6	-	-	-	-	-
Specific conductivity	µS/cm	303	331	446	246	469	80	0	6	-	-	-	-	-
Hardness, as $CaCO_3$	mg/L	153	167	228	107	229	49	0	6	-	-	-	-	-
Total alkalinity, as $CaCO_3$	mg/L	145	168	244	121	258	52	0	6	-	-	-	-	-
Total dissolved solids	mg/L	212	236	306	190	312	51	0	6	-	-	-	-	-
Total suspended solids	mg/L	3.0	-	5.3	<1.0	6.0	-	2	6	-	-	-	-	-
Total organic carbon	mg/L	24	21	27	5.9	28	8.1	0	6	-	-	-	-	-
Dissolved organic carbon	mg/L	25	22	27	5.7	27	8.1	0	6	-	-	-	-	-
Colour	TCU	**99**[(S)]	**89**[(S)]	**121**[(S)]	**46**[(S)]	**125**[(S)]	31	0	5	-	-	-	-	100
Major Ions														
Bicarbonate	mg/L	176	205	297	148	315	63	0	6	-	-	-	-	-
Calcium	mg/L	49	68	152	28	181	57	0	6	-	-	-	-	-
Carbonate	mg/L	<5.0	-	5.0	<0.5	5.0	-	5	6	-	-	-	-	-
Chloride	mg/L	4.0	4.5	8.7	1.0	10	3.0	0	6	-	-	-	-	-
Magnesium	mg/L	13	14	19	9.0	20	4.0	0	6	-	-	-	-	-
Potassium	mg/L	1.0	1.1	1.5	0.77	1.6	0.29	0	6	-	-	-	-	-
Sodium	mg/L	8.3	8.2	9.0	7.0	9.0	0.82	0	6	-	-	-	-	-
Sulphate	mg/L	<1.0	-	1.0	0.59	1.0	-	3	6	-	-	-	-	-
Sulphide	mg/L	0.0068	0.0063	0.010	<0.002	0.010	0.0041	1	6	-	17	-	-	-
Nutrients and Biological Indicators														
Nitrate + nitrite	mg-N/L	<0.071	-	0.071	<0.01	0.071	-	4	6	-	-	-	-	-
Total ammonia	mg-N/L	0.050	-	0.067	<0.015	0.072	-	3	6	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	0.81	0.82	1.0	0.62	1.0	0.17	0	6	-	-	-	-	-
Total nitrogen (calculated)	mg-N/L	0.85	0.84	1.1	0.62	1.1	0.20	0	6	-	-	-	-	-
Total phosphorus	mg-P/L	0.024	0.025	0.039	0.011	0.040	0.012	0	6	-	-	-	-	-
Dissolved phosphorus	mg-P/L	0.016	0.016	0.026	0.0038	0.027	0.0083	0	6	-	-	-	-	-
Biochemical oxygen demand	mg/L	<2.0	-	2.0	<2.0	2.0	-	4	6	-	-	-	-	-
General Organics														
Naphthenic acids	mg/L	0.61	-	<1.0	0.10	<1.0	-	2	6	-	-	-	-	-
Phenol[f]	mg/L	<0.002	-	<0.002	-	-	-	1	1	-	-	-	-	-
Total phenolics[a]	mg/L	**0.0072**[(C, W)]	**0.0077**[(C, W)]	**0.011**[(C, W)]	**0.0039**[(W)]	**0.012**[(C, W)]	0.0029	0	5	-	80	100	-	-
Total recoverable hydrocarbons	mg/L	<2.0	-	<2.0	<1.0	<2.0	-	4	4	-	-	-	-	-
Total Metals														
Aluminum	µg/L	10	19	44	8.4	50	16	0	6	-	-	-	-	-
Antimony	µg/L	<0.05	-	0.050	0.015	0.050	-	3	6	-	-	-	-	-
Arsenic	µg/L	0.45	0.41	0.51	0.23	0.51	0.11	0	6	-	-	-	-	-
Barium	µg/L	29	33	47	21	50	10	0	6	-	-	-	-	-
Beryllium	µg/L	<0.1	-	0.10	<0.008	0.10	-	4	6	-	-	-	-	-
Boron	µg/L	23	23	29	16	30	5.0	0	6	-	-	-	-	-
Cadmium	µg/L	0.010	-	0.010	<0.002	<0.1	-	4	6	-	-	-	-	-
Chromium	µg/L	0.12	-	0.30	<0.1	0.30	-	3	6	-	-	-	-	-
Cobalt	µg/L	0.16	0.15	0.23	0.069	0.24	0.070	0	6	-	-	-	-	-
Copper	µg/L	0.10	0.20	0.56	0.060	0.68	0.24	1	6	-	-	-	-	-
Iron	µg/L	**859**[(S)]	**750**[(S)]	**1,000**[(S)]	**320**[(S)]	**1,000**[(S)]	298	0	6	-	-	-	-	100
Lead	µg/L	<0.1	-	0.10	0.0080	0.10	-	2	6	-	-	-	-	-
Lithium	µg/L	8.3	8.1	9.8	6.0	10	1.5	0	6	-	-	-	-	-
Manganese	µg/L	**120**[(S)]	**162**[(S)]	**388**[(S)]	42	**460**[(S)]	155	0	6	-	-	-	-	83
Mercury	µg/L	0.00098	0.0013	0.0026	0.00047	0.0030	0.00088	0	6	-	-	-	-	-
Methyl mercury	µg/L	0.00023	-	0.00023	<0.00008	0.00023	-	1	2	-	-	-	-	-
Molybdenum	µg/L	<0.1	-	0.10	0.024	0.10	-	3	6	-	-	-	-	-
Nickel	µg/L	0.18	-	0.43	<0.008	0.48	-	2	6	-	-	-	-	-
Selenium	µg/L	0.090	-	0.30	<0.04	0.30	-	3	6	-	-	-	-	-
Silver	µg/L	<0.01	-	0.010	<0.002	0.010	-	4	6	-	-	-	-	-
Strontium	µg/L	95	105	144	80	150	28	0	6	-	-	-	-	-
Thallium	µg/L	<0.1	-	0.10	0.0012	0.10	-	3	6	-	-	-	-	-
Titanium	µg/L	1.2	-	2.3	<0.5	2.4	-	2	6	-	-	-	-	-
Uranium	µg/L	0.033	0.055	0.10	0.019	0.10	0.037	1	6	-	-	-	-	-
Vanadium	µg/L	0.16	-	0.20	0.10	0.20	-	2	6	-	-	-	-	-
Zinc	µg/L	1.3	1.4	3.2	0.40	3.6	1.2	1	6	-	-	-	-	-
Dissolved Metals														
Aluminum	µg/L	4.3	4.8	7.3	2.8	7.4	2.0	0	6	-	-	-	-	-
Antimony	µg/L	<0.05	-	0.050	0.015	0.050	-	3	6	-	-	-	-	-
Arsenic	µg/L	0.38	0.35	0.45	0.20	0.47	0.095	0	6	-	-	-	-	-
Barium	µg/L	25	28	39	20	40	8.0	0	6	-	-	-	-	-
Beryllium	µg/L	<0.1	-	0.10	<0.009	0.10	-	4	6	-	-	-	-	-
Boron	µg/L	23	22	26	16	26	3.5	0	6	-	-	-	-	-
Cadmium	µg/L	0.010	-	0.010	<0.002	<0.1	-	4	6	-	-	-	-	-
Chromium	µg/L	0.10	-	0.30	<0.1	0.30	-	3	6	-	-	-	-	-
Cobalt	µg/L	0.11	0.12	0.19	0.042	0.20	0.061	0	6	-	-	-	-	-
Copper	µg/L	0.15	-	0.54	<0.05	0.65	-	2	6	-	-	-	-	-
Iron	µg/L	254	**358**[(C)]	**656**[(C)]	170	**683**[(C)]	215	0	6	-	33	-	-	-
Lead	µg/L	0.014	-	0.10	<0.005	0.10	-	2	6	-	-	-	-	-
Lithium	µg/L	8.1	7.9	9.6	5.9	10	1.4	0	6	-	-	-	-	-
Manganese	µg/L	36	95	291	9.0	350	130	0	6	-	-	-	-	-
Mercury	µg/L	<0.05	-	0.050	0.00039	0.050	-	2	6	-	-	-	-	-
Molybdenum	µg/L	0.055	-	0.10	0.024	0.10	-	2	6	-	-	-	-	-
Nickel	µg/L	0.16	-	0.38	<0.006	0.41	-	2	6	-	-	-	-	-
Selenium	µg/L	0.060	-	0.30	<0.04	0.30	-	2	6	-	-	-	-	-
Silver	µg/L	<0.01	-	0.010	<0.001	0.010	-	4	6	-	-	-	-	-
Strontium	µg/L	88	102	144	79	150	29	0	6	-	-	-	-	-
Thallium	µg/L	<0.1	-	0.10	0.00040	0.10	-	3	6	-	-	-	-	-
Titanium	µg/L	0.99	-	1.8	<0.5	2.0	-	2	6	-	-	-	-	-
Uranium	µg/L	0.026	0.054	0.10	0.020	0.10	0.037	1	6	-	-	-	-	-
Vanadium	µg/L	0.12	-	<0.2	0.090	<0.2	-	3	6	-	-	-	-	-
Zinc	µg/L	0.70	0.83	1.5	0.41	1.6	0.45	0	6	-	-	-	-	-

(a) Guideline is a minimum value, unless the background concentration or value is lower.
(b) Guideline is hardness dependent. The guideline range shown is based on the hardness range observed in the dataset (73 to 314 mg/L). The guideline is calculated based on the individual hardness value for each sample.
(c) For some samples, water hardness was greater than 250 mg/L. At this hardness, no BC MOE water quality guideline (recommended by GOA 2018) has been established for sulphate; however, the observed data were screened against the guideline for very hard water (i.e., 429 mg/L) for comparative purposes.
(d) Guideline is pH dependent. The guideline range shown is based on the pH range observed in the dataset (6.4 to 8.2). The guideline is calculated based on the individual pH for each sample.
(e) The ammonia guideline is pH and temperature dependent. The the minimum ammonia guideline (0.45 mg-N/L) is presented and was calculated based on the combination of field pH (8.0) and water temperature (18.6°C). Guidelines calculated with temperature values falling outside the defined range (i.e., 0°C to 30°C) should be used with caution, as the WQG does not necessarily accurately reflect toxic effects at temperature extremes. The guideline is calculated based on the individual field pH and temperature measurements for each sample.
(f) Due to a CCME guideline update, the method for analyzing phenol was changed in fall 2016 to better capture semi-volatile phenol species.
(g) Total phenolics primarily represents inorganic phenols and the analysis method might be ineffective at capturing the concentrations of many semi-volatile phenol species.
(h) Guideline is for chromium VI.
A = Concentration is below the recommended GOA (2018) DO guideline.
C = Concentration is higher than the chronic aquatic life GOA (2018) guideline, below the recommended DO guideline, or outside the recommended pH range.
W = Concentration is higher than the wildlife health (livestock) GOA (2018) guideline.
S = Concentration is higher than the Health Canada (2017) drinking water AO guideline or outside the recommended pH range.
Notes: **Bolded** concentrations are higher than water quality guidelines.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision *after* comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and identified as exceedances. Concentrations equal to the guideline values were not identified as exceedances.
In cases where 25% or more of data were <DL, no mean or standard deviation was calculated.

- = not applicable, no guideline, or no data available; µS/cm = microSiemens per centimetre; TCU = true colour unit; < = less than; mg-N/L = milligrams as nitrogen per litre; mg-P/L = milligrams as phosphorus per litre; µg/L = micrograms per litre; GOA = Government of Alberta; MAC = maximum acceptable concentrations; AO = aesthetic objectives; BC MOE = British Columbia Ministry of Environment; nd = number of non-detectable results; DL = detection limit; DO = dissolved oxygen.

APPENDIX VI

Sediment Quality Data from 2006 to 2018 Compared to Guidelines

Table VI-1: Baseline Phase Sediment Quality Data Compared to Guidelines, 2006 to 2010

Parameter	Unit [dry wt.]	CCME (1998) Guidelines:		Muskeg Creek Watershed							Muskeg River Watershed											
				Station KEL-1							Station MUR-D2						Station MUR-D3					
		ISQG	PEL	14-Sep-06	11-Sep-07	18-Sep-07	09-Sep-08	10-Sep-08	16-Sep-09	11-Sep-10	14-Sep-06	13-Sep-07	11-Sep-08	12-Sep-08	10-Sep-09	15-Sep-10	04-Oct-06	07-Sep-07	04-Sep-08	08-Sep-08	16-Sep-09	11-Sep-10
Particle Size																						
Sand content	%	-	-	93	92	-	9.0	-	-	56	80	60	-	-	88	64	31	26	69	-	-	85
Silt content	%	-	-	7.0	4.0	-	62	-	-	28	19	32	-	-	8.0	27	29	27	6.0	-	-	9.6
Clay content	%	-	-	<1.0	4.0	-	29	-	-	16	1.0	8.0	-	-	3.0	9.3	40	47	25	-	-	5.3
Moisture content	%	-	-	91	94	-	97	-	95	97	50	64	-	-	41	58	92	90	73	-	86	85
Carbon Content																						
Total organic carbon	%	-	-	31	36	-	38	-	34	33	3.6	5.2	-	-	1.1	5.5	25	30	7.6	-	22	24
Organics																						
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	-	-	<80	8.0	-	<5.0	-	<216	<10	<10	<5.0	<5.0	-	<10	<10	<5.0	<5.0	<5.0	-	<73	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	-	-	<5.0	13	-	530	-	30	<410	110	180	<5.0	-	68	71	<5.0	7.0	47	-	27	<90
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	-	-	320	3,000	-	3,600	-	334	822	1,200	2,900	110	-	856	829	52	740	2,600	-	712	867
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	-	-	130	2,000	-	2,500	-	258	452	1,100	2,100	62	-	743	647	630	71	1,800	-	326	305
Total petroleum hydrocarbons	mg/kg	-	-	450	5,000	-	6,600	-	620	1,270	2,400	5,200	170	-	1,670	1,550	680	820	4,400	-	1,070	1,170
Metals (Total)																						
Aluminum	mg/kg	-	-	3,410	-	-	2,630	-	2,670	2,680	770	3,120	700	-	1,040	4,010	2,890	1,300	1,360	-	1,940	1,380
Antimony	mg/kg	-	-	-	-	<0.2	-	-	-	0.15	-	-	-	-	-	<0.1	-	-	-	-	-	<0.1
Arsenic	mg/kg	5.9	17	2.5	-	3.3	3.0	-	1.9	1.5	1.1	1.3	0.6	-	0.57	1.7	2.8	2.3	1.1	-	2.0	2.3
Barium	mg/kg	-	-	56	-	76	49	-	62	58	19	94	9.9	-	27	100	302	245	70	-	188	216
Beryllium	mg/kg	-	-	<0.2	-	<1.0	<0.2	-	<0.2	<0.2	<0.2	0.2	<0.2	-	<0.2	0.3	0.3	<0.2	<0.2	-	<0.2	<0.2
Boron	mg/kg	-	-	18	-	-	15	-	23	-	<2.0	8.0	<2.0	-	<2.0	-	21	16	5.0	-	12	-
Cadmium	mg/kg	0.6	3.5	0.3	-	<0.5	0.3	-	0.48	0.35	<0.1	<0.1	<0.1	-	<0.1	<0.1	0.2	0.1	<0.1	-	0.12	0.11
Calcium	mg/kg	-	-	10,800	-	-	9,300	-	11,900	12,400	1,500	5,100	3,900	-	1,320	6,380	28,100	26,200	6,100	-	17,100	20,900
Chromium	mg/kg	37	90	6.6	-	7.4	5.0	-	6.5	5.0	1.6	8.1	1.3	-	2.4	8.5	7.6	4.6	3.4	-	5.3	4.3
Cobalt	mg/kg	-	-	3.0	-	3.0	2.4	-	2.3	2.8	0.9	3.1	0.9	-	1.2	3.5	2.7	2.0	1.2	-	1.9	2.1
Copper	mg/kg	36	197	6.6	-	9.0	6.9	-	**71**[(I)]	7.2	0.7	4.0	0.8	-	3.0	4.2	7.8	5.0	2.1	-	4.2	17
Iron	mg/kg	-	-	5,200	-	-	4,500	-	7,810	5,510	4,700	14,300	3,700	-	5,060	17,300	51,900	43,300	14,400	-	42,000	43,400
Lead	mg/kg	35	91	3.8	-	<5.0	4.9	-	3.2	6.7	0.8	3.8	0.8	-	1.2	3.9	3.0	1.8	1.2	-	1.8	1.6
Lithium	mg/kg	-	-	-	-	-	-	-	-	2.6	-	-	-	-	-	5.4	-	-	-	-	-	1.5
Magnesium	mg/kg	-	-	1,650	-	-	1,480	-	1,560	1,610	810	1,060	2,470	-	496	1,390	2,060	2,020	980	-	1,540	1,610
Manganese	mg/kg	-	-	159	-	-	68	-	105	122	102	400	46	-	137	515	532	356	183	-	494	572
Mercury	mg/kg	0.17	0.49	<0.05	-	<0.05	0.1	-	<0.05	0.082	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05
Molybdenum	mg/kg	-	-	0.5	-	<1.0	0.8	-	0.92	1.2	<0.1	0.4	0.1	-	0.12	0.48	0.4	0.3	0.2	-	0.25	0.25
Nickel	mg/kg	-	-	11	-	13	10	-	27	14	1.3	6.6	1.5	-	2.4	6.6	8.4	5.5	2.6	-	5.1	5.0
Potassium	mg/kg	-	-	600	-	-	400	-	420	580	200	500	100	-	170	480	300	200	200	-	270	230
Selenium	mg/kg	-	-	0.8	-	0.9	0.7	-	1.1	0.69	<0.2	0.2	<0.2	-	<0.2	0.26	0.9	0.5	0.3	-	0.65	0.36
Silver	mg/kg	-	-	<0.2	-	<1.0	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	-	<0.2	<0.2
Sodium	mg/kg	-	-	300	-	-	300	-	380	400	<100	100	<100	-	<100	<100	200	100	100	-	150	100
Strontium	mg/kg	-	-	39	-	-	32	-	39	42	6.0	20	6.0	-	4.9	22	77	73	20	-	47	56
Thallium	mg/kg	-	-	<0.05	-	<1.0	<0.05	-	0.078	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	0.06	<0.05	<0.05	-	<0.05	<0.05
Titanium	mg/kg	-	-	54	-	-	17	-	45	38	20	66	23	-	24	52	28	37	30	-	31	36
Uranium	mg/kg	-	-	0.39	-	<2.0	0.48	-	0.67	0.45	0.07	0.37	0.15	-	0.12	0.35	0.43	0.26	0.16	-	0.28	0.19
Vanadium	mg/kg	-	-	9.1	-	12	10	-	8.9	19	2.5	16	3.0	-	4.5	16	16	9.8	5.6	-	9.0	8.6
Zinc	mg/kg	123	315	72	-	80	59	-	82	57	6.0	29	6.0	-	9.4	29	51	34	15	-	30	26
Target PAHs and Alkylated PAHs																						
Acenaphthene	mg/kg	0.0067	0.089	0.0026	**0.0075**[(I)]	-	-	0.005	0.0033	0.0026	0.0014	**0.0073**[(I)]	-	<0.00016	0.0013	0.0034	<0.0012	<0.0021	-	<0.0007	<0.0003	<0.00043
C1 substituted acenaphthene	mg/kg	-	-	0.032	<0.0027	-	-	0.038	<0.0022	0.036	0.00087	<0.0038	-	<0.00013	0.00035	0.0011	<0.00095	<0.0012	-	<0.00049	<0.00035	0.00037
Acenaphthylene	mg/kg	0.0059	0.13	<0.0024	<0.0026	-	-	0.0006	<0.00047	<0.0006	<0.00073	<0.0065	-	<0.00012	<0.00012	<0.00054	<0.00063	<0.0011	-	<0.00033	<0.00021	<0.00035
Anthracene	mg/kg	0.047	0.25	0.0019	0.0039	-	-	0.0036	0.002	<0.0025	<0.0053	<0.027	-	<0.0003	<0.0013	<0.0013	<0.00089	<0.0028	-	<0.00037	<0.00074	<0.0003
Dibenzo(a,h)anthracene	mg/kg	0.0062	0.14	0.0029	0.0029	-	-	<0.0012	<0.0018	<0.0015	<0.0066[(DL>)]	<0.011	-	<0.0011	0.0046	0.006	<0.0015	0.0019	-	<0.00072	<0.00069	<0.00057
Benzo(a)anthracene	mg/kg	0.032	0.39	0.0021	0.002	-	-	<0.003	<0.0027	0.002	<0.012	0.03	-	<0.00076	<0.0054	0.019	0.00084	0.0043	-	<0.00058	<0.0011	0.00093
C1 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	<0.0074	0.017	-	-	0.012	0.0079	0.017	0.2	0.47	-	0.03	0.13	0.038	0.044	0.02	-	0.0077	0.019	0.019
C2 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	<0.0043	0.015	-	-	0.01	0.0075	0.0079	0.21	0.32	-	0.021	0.12	0.21	0.026	0.0099	-	0.0028	0.0072	0.0082
Biphenyl	mg/kg	-	-	0.0093	0.0077	-	-	0.0077	0.008	0.0062	0.0012	<0.0026	-	0.00012	0.00047	<0.0011	0.0035	0.0032	-	0.00091	0.003	0.0012
C1 substituted biphenyl	mg/kg	-	-	0.023	0.011	-	-	0.0024	0.021	0.004	0.0018	<0.0026	-	<0.00017	<0.00024	0.002	<0.00061	0.0038	-	0.00065	0.00081	0.00098
C2 substituted biphenyl	mg/kg	-	-	0.063	0.053	-	-	0.0089	0.11	0.02	0.0072	0.019	-	0.00072	0.0042	0.014	0.0013	0.019	-	0.0046	0.013	0.0077
Chrysene	mg/kg	0.057	0.86	0.0051	0.0055	-	-	0.005	0.0032	0.0042	**0.099**[(I)]	**0.21**[(I)]	-	0.011	**0.058**[(I)]	**0.14**[(I)]	0.013	0.0099	-	0.0054	0.011	0.0081

Table VI-1: Baseline Phase Sediment Quality Data Compared to Guidelines, 2006 to 2010

Parameter	Unit [dry wt.]	CCME (1998) Guidelines:		Muskeg Creek Watershed							Muskeg River Watershed											
				Station KEL-1							Station MUR-D2						Station MUR-D3					
		ISQG	PEL	14-Sep-06	11-Sep-07	18-Sep-07	09-Sep-08	10-Sep-08	16-Sep-09	11-Sep-10	14-Sep-06	13-Sep-07	11-Sep-08	12-Sep-08	10-Sep-09	15-Sep-10	04-Oct-06	07-Sep-07	04-Sep-08	08-Sep-08	16-Sep-09	11-Sep-10
C1 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	0.01	0.01	-	-	0.015	0.011	0.016	0.21	0.66	-	0.03	0.22	0.51	0.025	0.022	-	0.02	0.016	0.018
C2 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	0.012	0.011	-	-	0.016	0.017	0.037	0.36	0.79	-	0.042	0.4	0.61	0.028	0.019	-	0.0096	0.024	0.024
Dibenzothiophene	mg/kg	-	-	0.0017	0.002	-	-	<0.0019	<0.0028	0.0027	<0.0046	<0.024	-	<0.00019	<0.0026	<0.0059	0.00088	0.001	-	<0.00021	0.00097	0.00089
C1 substituted dibenzothiophene	mg/kg	-	-	<0.0014	0.003	-	-	0.0048	0.0072	0.0059	0.033	0.056	-	0.0036	0.025	0.029	0.0013	<0.0012	-	0.002	0.0048	0.0056
C2 substituted dibenzothiophene	mg/kg	-	-	0.0098	0.023	-	-	0.0076	0.0094	0.019	0.53	1.9	-	0.019	0.42	1.4	0.036	0.039	-	0.015	0.027	0.036
C3 substituted dibenzothiophene	mg/kg	-	-	0.011	0.027	-	-	0.0066	0.013	0.017	1.2	4.7	-	0.11	1.2	3.4	0.068	0.051	-	0.017	0.042	0.059
C4 substituted dibenzothiophene	mg/kg	-	-	0.0091	0.029	-	-	0.0071	0.012	0.014	1.0	4.4	-	0.15	1.2	3.0	0.083	0.059	-	0.014	0.04	0.048
Fluoranthene	mg/kg	0.021	0.14	0.01	0.017	-	-	0.011	0.012	0.0098	<0.0061	0.017	-	<0.0003	0.0027	<0.0031	0.0021	0.0022	-	0.001	0.0014	0.0014
Benzo(b,j,k)fluoranthene[(a)]	mg/kg	-	-	0.0076	0.0036	-	-	0.0088	0.0029	0.0087	0.018	<0.019	-	0.0033	0.012	0.057	0.0061	0.003	-	0.0019	0.0042	0.0033
Fluorene	mg/kg	-	-	0.013	0.011	-	-	0.017	0.0059	0.011	<0.0036	<0.0052	-	<0.000099	<0.00091	0.002	0.0019	<0.00077	-	<0.00018	0.0022	0.0013
C1 substituted fluorene	mg/kg	-	-	0.057	0.083	-	-	0.05	0.051	0.033	0.033	0.11	-	0.0015	0.021	0.048	0.027	0.016	-	0.0046	0.015	0.0083
C2 substituted fluorene	mg/kg	-	-	0.027	0.074	-	-	0.04	0.064	0.044	0.12	0.57	-	0.0058	0.13	0.41	0.033	0.028	-	0.015	0.0088	0.018
C3 substituted fluorene	mg/kg	-	-	0.028	0.072	-	-	0.026	0.043	0.055	0.27	1.2	-	0.0045	0.31	1.2	0.044	0.044	-	<0.00098	0.026	0.034
Naphthalene	mg/kg	0.035	0.39	**0.036**[(I)]	-	-	-	0.02	-	-	0.0023	0.0034	-	0.0013	0.0014	0.0025	0.0065	0.015	-	0.0082	0.0035	0.0096
C1 substituted naphthalene	mg/kg	-	-	0.023	0.027	-	-	0.012	0.015	0.015	0.0031	<0.0045	-	0.0002	0.0016	0.0043	0.0021	0.0076	-	0.004	0.0028	0.0031
C2 substituted naphthalene	mg/kg	-	-	0.093	0.52	-	-	0.22	0.14	0.066	0.016	0.03	-	0.0018	0.0091	0.016	0.023	0.031	-	0.0059	0.015	0.0083
C3 substituted naphthalene	mg/kg	-	-	0.069	0.028	-	-	0.023	0.037	0.024	0.052	0.042	-	0.0014	0.032	0.06	0.017	0.028	-	0.0074	0.015	0.015
C4 substituted naphthalene	mg/kg	-	-	0.012	0.065	-	-	0.011	0.027	0.025	0.15	0.72	-	<0.00062	0.12	0.44	0.018	0.045	-	0.006	0.0077	0.019
Benzo(g,h,i)perylene	mg/kg	-	-	0.0079	0.005	-	-	<0.0054	<0.0024	<0.0052	0.024	0.039	-	0.0035	0.017	0.026	0.023	0.025	-	<0.00078	<0.0044	<0.012
Phenanthrene	mg/kg	0.042	0.52	0.024	0.036	-	-	0.021	0.022	0.014	0.014	0.031	-	0.0014	0.013	0.026	0.0051	0.0061	-	<0.0029	<0.0061	0.0039
C1 substituted phenanthrene / anthracene	mg/kg	-	-	0.013	0.024	-	-	0.025	0.022	0.016	0.087	0.12	-	0.0028	0.046	0.17	0.007	0.0067	-	0.0061	0.0084	0.015
C2 substituted phenanthrene / anthracene	mg/kg	-	-	0.02	0.039	-	-	0.021	0.02	0.019	0.33	1.2	-	0.015	0.21	0.73	0.024	0.018	-	0.008	0.02	0.038
C3 substituted phenanthrene / anthracene	mg/kg	-	-	0.03	0.048	-	-	0.018	0.032	0.024	0.52	2.2	-	0.053	0.43	1.3	0.035	0.024	-	0.0088	0.021	0.042
C4 substituted phenanthrene / anthracene	mg/kg	-	-	0.14	0.12	-	-	0.06	0.12	0.063	1.3	4.5	-	0.23	1.3	3.3	0.55	0.66	-	0.15	0.41	2.5
Pyrene	mg/kg	0.053	0.88	0.0074	0.004	-	-	0.0069	0.0067	0.0058	0.031	0.048	-	0.0034	0.018	0.046	0.0066	0.0073	-	0.0033	0.0054	0.0053
C1 substituted fluoranthene / pyrene	mg/kg	-	-	0.018	0.024	-	-	0.013	0.027	0.024	0.17	0.44	-	0.025	0.26	0.67	0.021	0.025	-	0.011	0.038	0.09
C2 substituted fluoranthene / pyrene	mg/kg	-	-	0.011	0.011	-	-	0.014	0.02	0.024	0.42	0.97	-	0.063	0.62	1.4	0.049	0.032	-	0.018	0.15	0.051
C3 substituted fluoranthene / pyrene	mg/kg	-	-	0.0019	0.0076	-	-	0.003	0.0082	0.015	0.33	0.93	-	0.061	0.68	1.6	0.026	0.022	-	0.0071	0.037	0.035
Indeno(c,d-123)pyrene	mg/kg	-	-	0.0042	0.0059	-	-	0.0066	<0.0036	0.0044	0.011	0.027	-	0.0013	0.0077	0.014	0.0024	0.0034	-	0.002	0.0022	0.0027
Benzo(a)pyrene	mg/kg	0.032	0.78	<0.0032	<0.002	-	-	0.0023	<0.0015	0.0022	0.012	0.03	-	0.0011	0.0056	0.013	0.0022	<0.002	-	<0.00075	<0.00064	0.0011
Retene	mg/kg	-	-	0.11	0.058	-	-	0.03	0.05	0.016	0.15	0.31	-	0.012	0.072	0.18	0.34	0.52	-	0.13	0.35	2.3

(a) Results were combined for benzo(b,j,k)fluoranthene, benzo(b,j)fluoranthene and benzo(k)fluoranthene.

I = Value higher than the CCME (1998) Interim Sediment Quality Guideline.

DL>I = Analytical detection limit is higher than the CCME (1998) interim sediment quality guideline.

Note: **Bolded** values are higher than sediment quality guidelines.

dry wt. = dry weight; CCME = Canadian Council of Ministers of the Environment; ISQG = interim sediment quality guidelines; PEL = probable effects level; < = less than; > = greater than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles; - = no guideline or data available; DL = detection limit.

Table VI-2: Operational Phase Sediment Quality Data Compared to Guidelines, 2011 to 2018

Parameter	Unit [dry wt.]	CCME (1998) Guidelines		Firebag River Watershed				Muskeg River Watershed					
				Station FR-1				Station AB07DA0440					
		ISQG	PEL	18-Oct-13	21-Oct-14	26-Oct-17	15-Oct-18	17-Oct-13	22-Oct-14	15-Nov-15	24-Oct-16	24-Oct-17	17-Oct-18
Particle Size													
Sand content	%	-	-	93	73	96	96	98	97	97	95	95	96
Silt content	%	-	-	4.9	22	2.3	<2.0	<2.0	<2.0	<2.0	3.1	3.4	<2.0
Clay content	%	-	-	<2.0	5.0	2.1	2.4	<2.0	<2.0	<2.0	<2.0	<2.0	3.2
Moisture content	%	-	-	21	34	12	19	19	19	21	24	31	37
Carbon Content													
Total inorganic carbon	%	-	-	<0.02	1.0	<0.05	<0.05	0.04	<0.02	<0.02	<0.05	0.29	<0.05
Total organic carbon	%	-	-	4.1	2.4	1.2	1.0	0.088	0.23	0.26	0.51	1.1	2.8
Total carbon	%	-	-	3.0	3.4	1.1	0.6	0.12	0.23	0.19	0.54	1.4	0.98
Organics													
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	-	-	<12	<12	<10	<10	<12	<12	<12	<12	<10	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	-	-	720	120	230	180	<10	<10	<10	<10	<10	<10
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	-	-	5,900	1,500	2,300	1,600	<50	<50	59	<50	120	380
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	-	-	3,600	920	1,400	980	<50	<50	<50	<50	<50	55
Total petroleum hydrocarbons	mg/kg	-	-	13,000	4,200	5,700	4,400	<50	<50	<50	84	59	98
Metals (Total)													
Aluminum	mg/kg	-	-	640	1,400	640	540	520	670	700	800	650	970
Antimony	mg/kg	-	-	<1.0	<1.0	<0.5	<0.5	<1.0	<1.0	<0.5	<0.5	<0.5	<0.5
Arsenic	mg/kg	5.9	17	1.4	1.6	1.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Barium	mg/kg	-	-	<10	27	7.6	11	<10	<10	5.3	10	13	18
Beryllium	mg/kg	-	-	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Boron	mg/kg	-	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Cadmium	mg/kg	0.6	3.5	0.11	0.14	<0.05	<0.05	<0.1	<0.1	<0.05	<0.05	<0.05	<0.05
Calcium	mg/kg	-	-	1,600	2,600	5,100	1,800	1,000	950	1,300	1,600	1,900	2,000
Chromium	mg/kg	37	90	1.1	1.9	1.9	1.8	<1.0	<1.0	<1.0	1.1	2.1	2.0
Cobalt	mg/kg	-	-	<1.0	2.0	1.1	0.68	<1.0	<1.0	<0.5	0.61	0.75	0.85
Copper	mg/kg	36	197	<5.0	<5.0	1.5	<1.0	<5.0	<5.0	<1.0	<1.0	<1.0	<1.0
Iron	mg/kg	-	-	5,400	3,200	4,900	2,500	1,200	1,800	2,000	1,600	2,600	4,000
Lead	mg/kg	35	91	<1.0	2.1	1.1	1.0	<1.0	<1.0	<0.5	0.51	0.53	0.77
Lithium	mg/kg	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Magnesium	mg/kg	-	-	850	1,300	2,900	1,100	590	460	730	590	650	700
Manganese	mg/kg	-	-	23	33	30	39	16	14	20	18	33	43
Mercury	mg/kg	0.17	0.49	<0.05	0.055	<0.05	0.11	<0.05	<0.05	0.076	<0.05	<0.05	0.066
Molybdenum	mg/kg	-	-	0.67	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Nickel	mg/kg	-	-	3.3	4.2	2.7	1.5	<1.0	<1.0	<1.0	<1.0	1.5	1.4
Potassium	mg/kg	-	-	91	140	82	38	77	55	< 25	33	66	89
Selenium	mg/kg	-	-	0.51	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Silver	mg/kg	-	-	<1.0	<1.0	<0.2	<0.2	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2
Sodium	mg/kg	-	-	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50	< 50
Strontium	mg/kg	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Thallium	mg/kg	-	-	<0.3	<0.3	<0.1	<0.1	<0.3	<0.3	<0.1	<0.1	<0.1	<0.1
Titanium	mg/kg	-	-	25	39	35	38	23	17	23	23	25	29
Uranium	mg/kg	-	-	<1.0	<1.0	0.26	<0.2	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2
Vanadium	mg/kg	-	-	7.8	9.5	4.7	4.3	1.1	1.4	1.5	1.7	2.3	2.7
Zinc	mg/kg	123	315	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Target PAHs and Alkylated PAHs													
Acenaphthene	mg/kg	0.0067	0.089	<0.005	<0.0045	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
C1 substituted acenaphthene	mg/kg	-	-	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Acenaphthylene	mg/kg	0.0059	0.13	<0.015[DL>I]	<0.0044	**0.0081**[I]	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Anthracene	mg/kg	0.047	0.25	<0.0069	<0.0024	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0018
Dibenzo(a,h)anthracene	mg/kg	0.0062	0.14	<0.023[DL>I]	<0.001	**0.015**[I]	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo(a)anthracene	mg/kg	0.032	0.39	<0.035[DL>I]	<0.0005	0.01	<0.005	<0.0005	<0.0005	0.00065	<0.0005	<0.0005	<0.0005
Benzo(c)phenanthrene	mg/kg	-	-	<0.05	<0.005	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	1.4	0.38	0.34	0.27	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	-	1.7	0.34	0.19	0.41	<0.005	<0.005	<0.005	<0.005	<0.005	0.015
Biphenyl	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted biphenyl	mg/kg	-	-	0.0084	0.0081	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted biphenyl	mg/kg	-	-	0.049	0.0058	0.0088	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chrysene	mg/kg	0.057	0.86	**0.35**[I]	<0.0005	<0.005	<0.005	<0.0005	<0.0005	<0.0005	0.0011	<0.0005	<0.0005
C1 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	1.2	0.19	0.33	0.25	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	5.8	1.1	1.8	1.3	<0.005	<0.005	<0.005	<0.005	<0.005	0.016
C3 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	3.7	0.98	0.88	0.98	<0.005	<0.005	<0.005	<0.005	<0.005	0.025
C4 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	1.1	0.43	0.2	0.29	<0.005	<0.005	<0.005	<0.005	<0.005	0.0089
Dibenzothiophene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted dibenzothiophene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted dibenzothiophene	mg/kg	-	-	0.31	0.11	0.24	0.25	<0.005	<0.005	<0.005	<0.005	<0.005	0.016
C3 substituted dibenzothiophene	mg/kg	-	-	0.52	0.17	0.34	0.54	<0.005	<0.005	<0.005	<0.005	<0.005	0.012
C4 substituted dibenzothiophene	mg/kg	-	-	2.9	0.17	1.1	0.87	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	mg/kg	0.11	2.4	<0.027	<0.0055	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzo(b,j,k)fluoranthene[a]	mg/kg	-	-	-	-	-	-	-	-	-	-	-	-
Benzo(b,j)fluoranthene	mg/kg	-	-	0.13	<0.0078	0.053	0.043	<0.001	<0.001	<0.0005	0.00079	0.00073	0.0016
Benzo(k)fluoranthene	mg/kg	-	-	<0.0073	<0.05	0.0064	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Fluorene	mg/kg	0.021	0.14	<0.005	<0.0005	<0.005	<0.005	<0.0005	<0.0005	0.00077	<0.0005	0.0029	0.0011
C1 substituted fluorene	mg/kg	-	-	0.046	0.01	0.0086	0.03	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted fluorene	mg/kg	-	-	0.28	0.031	0.046	0.052	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted fluorene	mg/kg	-	-	1.0	0.21	<0.005	0.29	<0.005	<0.005	<0.005	<0.005	0.0081	0.025
Naphthalene	mg/kg	0.035	0.39	<0.005	0.0017	<0.005	<0.005	0.0011	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
1-Methylnaphthalene	mg/kg	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
2-Methylnaphthalene	mg/kg	-	-	<0.05	<0.005	<0.05	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C1 substituted naphthalene	mg/kg	-	-	0.0069	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted naphthalene	mg/kg	-	-	0.063	0.025	0.03	0.048	0.0089	<0.005	<0.005	<0.005	0.017	0.022
C3 substituted naphthalene	mg/kg	-	-	0.098	0.029	0.016	0.022	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C4 substituted naphthalene	mg/kg	-	-	0.23	0.049	0.037	0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Perylene	mg/kg	-	-	0.18	<0.0084	0.067	0.052	<0.005	<0.005	0.0075	0.012	0.022	0.024
Benzo(g,h,i)perylene	mg/kg	-	-	0.058	<0.001	0.032	0.029	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phenanthrene	mg/kg	0.042	0.52	<0.012	<0.0065	<0.005	<0.005	<0.0005	<0.0005	<0.0005	<0.0005	0.00087	0.0011
C1 substituted phenanthrene / anthracene	mg/kg	-	-	<0.005	0.048	0.03	0.026	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted phenanthrene / anthracene	mg/kg	-	-	0.5	0.12	0.12	0.14	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C3 substituted phenanthrene / anthracene	mg/kg	-	-	1.2	0.24	0.42	0.52	<0.005	<0.005	<0.005	<0.005	0.013	0.021
C4 substituted phenanthrene / anthracene	mg/kg	-	-	3.6	0.32	1.2	0.93	<0.005	<0.005	<0.005	<0.005	0.038	0.031
Pyrene	mg/kg	0.053	0.88	**0.24**[I]	**0.076**[I]	**0.082**[I]	**0.072**[I]	<0.0005	<0.0005	<0.0005	0.00066	0.0016	0.0016
C1 substituted fluoranthene / pyrene	mg/kg	-	-	1.4	0.22	0.38	0.29	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
C2 substituted fluoranthene / pyrene	mg/kg	-	-	4.1	0.75	1.3	1.0	<0.005	<0.005	<0.005	<0.005	0.17	0.092
C3 substituted fluoranthene / pyrene	mg/kg	-	-	13	2.7	3.2	3.2	<0.005	<0.005	<0.005	<0.005	0.02	0.11
C4 substituted fluoranthene / pyrene	mg/kg	-	-	7.6	0.89	1.9	2.3	<0.005	<0.005	<0.005	<0.005	<0.005	0.051
Indeno(c,d-123)pyrene	mg/kg	-	-	0.037	<0.0079	0.016	0.015	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo(a)pyrene	mg/kg	0.032	0.78	**0.076**[I]	**0.084**[I]	0.031	0.028	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzo(e)pyrene	mg/kg	-	-	<0.05	<0.005	0.073	0.067	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Retene	mg/kg	-	-	0.073	0.026	<0.005	0.017	<0.005	<0.005	0.0088	<0.005	0.048	0.034
PANHs													
Quinoline	mg/kg	-	-	<0.1	<0.01	-	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acridine	mg/kg	-	-	<0.1	<0.01	<0.1	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

(a) Results were combined for benzo(b,j,k)fluoranthene, benzo(b,j)fluoranthene and benzo(k)fluoranthene.

I = Value higher than the CCME (1998) Interim Sediment Quality Guideline.

DL>I = Analytical detection limit is higher than the CCME (1998) interim sediment quality guideline.

Note: **Bolded** values are higher than sediment quality guidelines.

dry wt. = dry weight; CCME = Canadian Council of Ministers of the Environment; ISQG = interim sediment quality guidelines; PEL = probable effects level; < = less than; > = greater than; mg/kg = milligrams per kilogram; PAHs = polycyclic aromatic hydrocarbons; PANHs = polycyclic aromatic nitrogen heterocycles; - = no guideline or data available; DL = detection limit.

Table VI-2: Operational Phase Sediment Quality Data Compared to Guidelines, 2011 to 2018

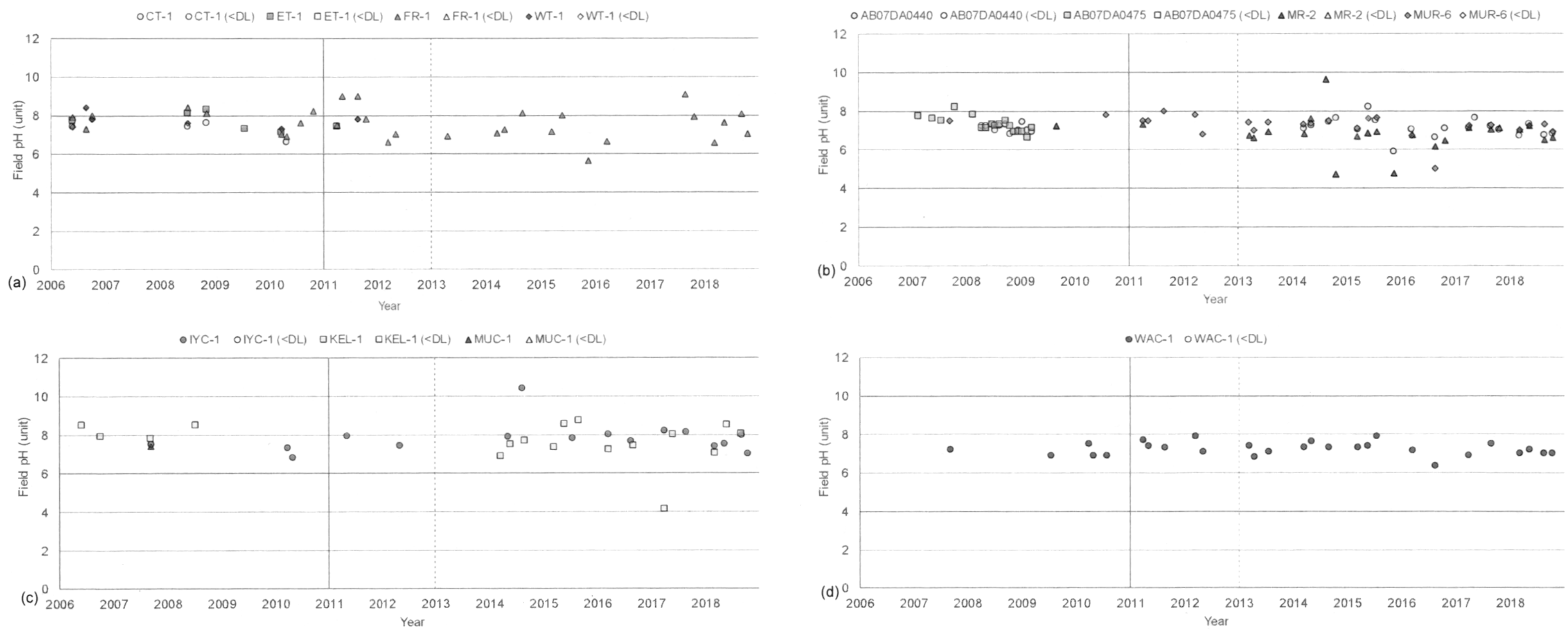
Parameter	Unit [dry wt.]	Muskeg River Watershed										
			Station MUR-D2					Station MUR-D3				
		17-Oct-18	15-Sep-11	11-Sep-12	08-Sep-13	04-Sep-14	14-Sep-15	10-Sep-11	11-Sep-12	05-Sep-13	05-Sep-14	11-Sep-15
Particle Size												
Sand content	%	-	72	82	99	88	99	82	67	83	83	90
Silt content	%	-	22	14	<1.0	6.4	0.52	12	28	11	9.5	7.0
Clay content	%	-	6.1	4.2	<1.0	5.6	0.64	6.6	4.5	6.0	7.5	2.7
Moisture content	%	55	48	52	20	20	31	79	87	37	57	56
Carbon Content												
Total inorganic carbon	%	-	-	-	-	-	-	-	-	-	-	-
Total organic carbon	%	-	3.3	2.2	0.13	1.1	0.14	10	25	3.1	5.8	4.8
Total carbon	%	-	-	-	-	-	-	-	-	-	-	-
Organics												
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	<20	<20	<20	<10	<10	<10	<50	<80	<10	<30	<20
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	<22	44	42	<20	67	<20	<70	<83	<20	<24	<30
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	240	1,080	801	50	644	187	111	1,020	67	225	182
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	<110	1,170	695	43	558	164	74	427	56	131	110
Total petroleum hydrocarbons	mg/kg	-	2,290	1,540	93	1,270	351	185	1,450	123	356	292
Metals (Total)												
Aluminum	mg/kg	-	3,440	1,340	507	1,660	451	592	3,080	1,340	2,070	1,400
Antimony	mg/kg	-	0.1	0.54	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	<0.1	<0.1
Arsenic	mg/kg	-	1.3	0.77	0.46	0.67	0.32	0.63	3.5	0.78	1.1	0.75
Barium	mg/kg	-	85	37	6.8	23	7.2	273	289	46	59	29
Beryllium	mg/kg	-	<0.2	<0.2	<0.2	<0.2	<0.1	<0.2	0.26	<0.2	<0.2	<0.1
Boron	mg/kg	-	-	-	-	-	<5.0	-	-	-	-	<5.0
Cadmium	mg/kg	-	<0.1	<0.1	<0.1	<0.1	<0.02	0.23	0.17	<0.1	<0.1	<0.02
Calcium	mg/kg	-	4,530	2,580	2,640	1,950	1,650	247,000	30,000	5,540	8,630	4,660
Chromium	mg/kg	-	7.2	3.7	0.8	3.3	0.79	2.5	9.1	2.4	3.6	2.5
Cobalt	mg/kg	-	2.9	1.3	0.66	1.0	0.45	0.91	3.1	0.96	1.5	1.0
Copper	mg/kg	-	3.8	2.0	<0.5	1.1	<0.5	2.0	6.5	1.2	1.7	0.98
Iron	mg/kg	-	14,500	5,930	1,520	3,940	1,610	8,700	73,200	9,540	11,800	7,120
Lead	mg/kg	-	3.4	1.5	0.59	1.3	<0.5	<0.5	2.6	0.84	1.2	0.82
Lithium	mg/kg	-	6.1	1.1	1.0	1.9	<2.0	1.7	2.7	1.2	2.8	<2.0
Magnesium	mg/kg	-	1,020	648	1,310	817	902	7,870	2,780	883	1,410	986
Manganese	mg/kg	-	874	246	51	121	61	457	515	94	241	81
Mercury	mg/kg	-	<0.05	<0.05	<0.05	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05	0.0089
Molybdenum	mg/kg	-	0.4	0.27	<0.1	0.14	<0.1	1.6	0.46	<0.1	<0.1	<0.1
Nickel	mg/kg	-	6.2	2.6	0.93	2.1	0.77	6.6	7.7	1.9	2.9	2.1
Potassium	mg/kg	-	460	190	83	220	<100	<100	520	204	340	240
Selenium	mg/kg	-	<0.2	0.22	<0.2	<0.2	<0.2	0.49	0.72	<0.2	<0.2	<0.2
Silver	mg/kg	-	<0.2	<0.2	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	<0.2	<0.1
Sodium	mg/kg	-	<100	<100	<100	<100	<50	220	160	<100	<100	<50
Strontium	mg/kg	-	18	9.8	6.8	8.6	4.1	800	72	17	26	14
Thallium	mg/kg	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Titanium	mg/kg	-	58	33	24	41	15	18	51	31	38	33
Uranium	mg/kg	-	0.31	0.16	0.17	0.12	0.058	0.21	0.36	0.16	0.2	0.14
Vanadium	mg/kg	-	15	6.7	1.6	5.4	1.4	3.5	17	4.3	6.2	3.9
Zinc	mg/kg	-	23	16	6.0	8.4	3.1	20	51	9.4	12	9.2
Target PAHs and Alkylated PAHs												
Acenaphthene	mg/kg	-	0.00077	0.0009	0.00011	0.0007	<0.0011	<0.00034	<0.00094	0.00036	<0.00022	<0.00015
C1 substituted acenaphthene	mg/kg	-	0.00015	0.00019	0.000059	<0.00031	<0.0009	<0.00028	<0.00055	0.00019	<0.00023	<0.00016
Acenaphthylene	mg/kg	-	0.00046	<0.0001	0.000059	<0.00015	<0.0005	<0.00028	<0.00035	0.00012	<0.000091	<0.000066
Anthracene	mg/kg	-	0.0015	<0.00064	0.00017	0.00055	<0.001	0.001	0.0011	0.00022	<0.00027	0.0001
Dibenzo(a,h)anthracene	mg/kg	-	**0.0065**[f]	0.0052	0.00047	<0.0034	<0.0049	<0.00031	<0.0019	0.00024	<0.00071	<0.00042
Benzo(a)anthracene	mg/kg	-	0.0065	<0.0042	0.00037	0.0035	<0.0036	0.00037	0.0014	0.00041	<0.00044	0.00028
Benzo(c)phenanthrene	mg/kg	-	-	-	-	-	-	-	-	-	-	-
C1 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	0.26	0.12	0.021	0.086	0.052	0.0015	0.018	0.011	0.015	0.013
C2 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	-	0.11	0.076	0.017	0.057	0.031	0.0015	0.021	0.0074	0.0059	0.0074
Biphenyl	mg/kg	-	0.0011	0.00057	0.0001	0.00021	<0.0008	0.0018	0.0021	0.00058	0.00039	0.00033
C1 substituted biphenyl	mg/kg	-	0.00062	0.00069	0.0003	0.00045	<0.00064	0.00081	0.0011	0.00059	0.00049	0.00021
C2 substituted biphenyl	mg/kg	-	0.0071	0.0018	0.0019	0.0023	<0.001	0.0033	0.0042	0.0022	0.0014	0.00049
Chrysene	mg/kg	-	0.051	0.055	0.0048	0.034	0.02	0.003	0.013	0.00051	0.0063	0.0048
C1 substituted benzo(a)anthracene / chrysene	mg/kg	-	0.17	0.17	0.015	0.11	0.05	0.0034	0.034	0.0076	0.013	0.012
C2 substituted benzo(a)anthracene / chrysene	mg/kg	-	0.35	0.26	0.028	0.17	0.1	0.0029	0.029	0.013	0.017	0.019
C3 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	-	-	-	0.03	-	-	-	-	0.0074
C4 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	-	-	-	<0.0037	-	-	-	-	0.0023
Dibenzothiophene	mg/kg	-	0.0042	0.004	0.00018	0.0011	<0.00052	0.00087	0.0021	0.00057	0.00042	0.00027
C1 substituted dibenzothiophene	mg/kg	-	0.033	0.035	0.00015	0.0058	<0.002	0.0035	0.0082	0.0032	0.0026	0.0021
C2 substituted dibenzothiophene	mg/kg	-	0.22	0.15	0.0069	0.22	0.009	0.03	0.029	0.011	0.013	0.011
C3 substituted dibenzothiophene	mg/kg	-	0.57	0.4	0.017	0.59	0.071	0.031	0.056	0.015	0.02	0.02
C4 substituted dibenzothiophene	mg/kg	-	0.57	0.5	0.029	0.43	0.12	0.017	0.046	0.012	0.02	0.021
Fluoranthene	mg/kg	-	0.0017	0.0024	0.00014	0.0015	<0.0016	0.0024	0.0026	0.00052	0.00048	0.0004
Benzo(b,j,k)fluoranthene[a]	mg/kg	-	0.012	<0.0034	0.0012	0.0068	-	0.00099	0.0027	0.0021	<0.0004	-
Benzo(b,j)fluoranthene	mg/kg	-	-	-	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	mg/kg	-	-	-	-	-	-	-	-	-	-	-
Fluorene	mg/kg	-	0.0015	0.0014	0.000077	0.00048	<0.00081	0.0024	0.0035	0.00055	0.00065	0.00044
C1 substituted fluorene	mg/kg	-	0.015	0.015	0.00095	0.0045	<0.0014	0.0069	0.022	0.003	0.0017	0.0015
C2 substituted fluorene	mg/kg	-	0.064	0.06	0.0031	0.062	<0.0017	0.015	0.027	0.0048	0.0041	0.0035
C3 substituted fluorene	mg/kg	-	0.17	0.14	0.0089	0.16	<0.0058	0.036	0.039	0.0072	0.0055	0.0053
Naphthalene	mg/kg	-	0.0016	0.00096	0.0004	0.0004	0.00092	<0.0075	0.003	0.00085	0.00043	0.00063
1-Methylnaphthalene	mg/kg	-	-	-	-	-	<0.00085	-	-	-	-	0.00031
2-Methylnaphthalene	mg/kg	-	-	-	-	-	<0.00079	-	-	-	-	0.00035
C1 substituted naphthalene	mg/kg	-	0.0032	0.0021	0.00037	0.0006	<0.00079	0.0015	0.0045	0.0011	0.00072	0.00037
C2 substituted naphthalene	mg/kg	-	0.024	0.013	0.0017	0.0041	<0.0024	0.079	0.12	0.0058	0.0031	0.0017
C3 substituted naphthalene	mg/kg	-	0.07	0.034	0.0009	0.012	<0.0014	0.0059	0.015	0.0079	0.0039	0.0023
C4 substituted naphthalene	mg/kg	-	0.14	0.047	0.0031	0.068	<0.00092	0.0093	0.0062	0.0064	0.0048	0.0037
Perylene	mg/kg	-	-	-	-	-	0.021	-	-	-	-	0.038
Benzo(g,h,i)perylene	mg/kg	-	0.029	0.018	0.0023	0.011	0.0091	0.00076	<0.0033	0.0047	0.0021	0.0017
Phenanthrene	mg/kg	-	0.014	0.015	0.00057	0.0067	0.0015	0.0042	0.0088	0.0021	0.0019	0.0014
C1 substituted phenanthrene / anthracene	mg/kg	-	<0.036	0.031	0.000048	0.043	<0.0029	0.011	0.017	0.0057	0.006	0.0048
C2 substituted phenanthrene / anthracene	mg/kg	-	0.16	0.11	0.0052	0.016	0.014	0.019	0.031	0.009	0.0096	0.0075
C3 substituted phenanthrene / anthracene	mg/kg	-	0.29	0.22	0.0099	0.25	0.027	0.024	0.034	0.0087	0.01	0.011
C4 substituted phenanthrene / anthracene	mg/kg	-	1.2	0.96	0.066	0.64	0.23	0.039	0.75	0.34	0.15	0.092
Pyrene	mg/kg	-	0.017	0.018	0.0016	0.011	0.0056	0.0081	0.0062	0.0026	0.003	0.0023
C1 substituted fluoranthene / pyrene	mg/kg	-	0.21	0.23	0.025	0.15	0.088	0.022	0.054	0.023	0.024	0.02
C2 substituted fluoranthene / pyrene	mg/kg	-	0.55	0.56	0.062	0.34	0.25	0.019	0.066	0.029	0.038	0.038
C3 substituted fluoranthene / pyrene	mg/kg	-	0.45	0.51	0.067	0.23	0.24	0.0047	0.048	0.02	0.034	0.03
C4 substituted fluoranthene / pyrene	mg/kg	-	-	-	-	-	0.098	-	-	-	-	0.017
Indeno(c,d-123)pyrene	mg/kg	-	0.012	0.01	0.0013	0.0046	<0.0054	0.00092	<0.0025	0.0016	0.0016	0.0014
Benzo(a)pyrene	mg/kg	-	0.0072	0.0072	0.00079	0.0033	<0.0057	0.00041	0.0024	0.00052	0.0008	0.00071
Benzo(e)pyrene	mg/kg	-	-	-	-	-	0.016	-	-	-	-	0.0026
Retene	mg/kg	-	0.061	0.041	0.0021	0.046	<0.0096	0.016	0.63	0.3	0.092	0.066
PANHs												
Quinoline	mg/kg	-	-	-	-	-	-	-	-	-	-	-
Acridine	mg/kg	-	-	-	-	-	-	-	-	-	-	-

Table VI-2: Operational Phase Sediment Quality Data Compared to Guidelines, 2011 to 2018

Parameter	Unit [dry wt.]	Muskeg Creek Watershed						Wapasu Creek Watershed						
		Station KEL-1						Station WAC-1						
		10-Sep-11	08-Sep-12	09-Sep-13	11-Sep-14	03-Sep-15	02-Sep-18	19-Oct-13	20-Oct-14	16-Nov-15	26-Oct-16	25-Oct-17	16-Oct-18	16-Oct-18
Particle Size														
Sand content	%	53	16	23	3.5	0.74	68	52	97	96	84	94	95	-
Silt content	%	45	70	67	88	87	28	26	<2.0	2.6	13	3.7	2.3	-
Clay content	%	2.3	14	10	8.9	12	3.5	22	<2.0	<2.0	2.6	2.3	2.6	-
Moisture content	%	94	94	95	93	94	93	20	17	15	41	32	31	33
Carbon Content														
Total inorganic carbon	%	-	-	-	-	-	0.44	0.75	<0.02	<0.2	0.42	0.19	<0.05	-
Total organic carbon	%	5.0	27	35	36	33	37	1.7	0.27	0.81	4.1	1.2	1.8	-
Total carbon	%	-	-	-	-	-	37	2.4	0.23	1.2	4.5	1.4	1.1	-
Organics														
Total volatile hydrocarbons (C_6-C_{10})	mg/kg	<160	<170	<1,000	<160	<170	<120	<12	<12	<12	<12	<10	<10	<10
Total extractable hydrocarbons (C_{11}-C_{16})	mg/kg	<213	<216	<146	<216	<210	42	<10	<10	<10	<10	13	<10	<10
Total extractable hydrocarbons (C_{17}-C_{34})	mg/kg	487	714	387	681	666	350	<50	<50	60	99	140	100	140
Total extractable hydrocarbons (C_{35}-C_{50})	mg/kg	366	409	192	486	352	<98	<50	<50	<50	<50	<50	<50	70
Total petroleum hydrocarbons	mg/kg	850	1,120	<1,000	1,170	1,020	<650	120	<50	90	470	<50	130	-
Metals (Total)														
Aluminum	mg/kg	4,130	3,130	3,350	2,990	3,740	3,400	4,800	390	560	2,200	730	820	-
Antimony	mg/kg	0.21	0.39	0.13	0.13	0.14	<0.5	<1.0	<1.0	<0.5	<0.5	<0.5	<0.5	-
Arsenic	mg/kg	2.1	2.0	1.5	1.8	1.8	2.0	1.3	<1.0	<1.0	<1.0	<1.0	<1.0	-
Barium	mg/kg	57	56	52	51	54	59	40	<10	8.2	42	19	19	-
Beryllium	mg/kg	0.21	<0.2	<0.2	<0.2	0.15	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	-
Boron	mg/kg	-	-	-	-	19	20	5.4	<2.0	<2.0	3.5	<2.0	<2.0	-
Cadmium	mg/kg	0.45	0.43	0.39	0.36	0.36	0.43	0.34	<0.1	0.11	<0.05	<0.05	<0.05	-
Calcium	mg/kg	12,000	11,100	13,000	10,300	12,300	13,000	19,000	660	7,900	3,700	1,600	1,900	-
Chromium	mg/kg	7.0	7.8	5.4	5.0	6.0	31	8.0	<1.0	**45**[l]	3.2	1.3	1.3	-
Cobalt	mg/kg	3.3	2.8	2.6	2.7	3.3	3.1	2.5	<1.0	0.72	1.2	0.65	0.83	-
Copper	mg/kg	9.7	8.2	6.6	7.0	7.0	8.6	8.8	<5.0	1.7	1.7	<1.0	<1.0	-
Iron	mg/kg	6,130	6,400	5,430	4,760	5,840	6,300	9,100	610	1,200	3,700	2,000	2,600	-
Lead	mg/kg	4.3	4.8	4.7	4.3	4.4	3.7	4.2	<1.0	0.74	1.4	0.62	0.64	-
Lithium	mg/kg	4.5	3.6	3.1	3.3	3.2	<10	<10	<10	<10	<10	<10	<10	-
Magnesium	mg/kg	2,190	1,700	1,670	1,540	1,900	18,00	5,200	280	4,600	700	380	370	-
Manganese	mg/kg	98	86	109	98	108	120	180	26	30	240	150	130	-
Mercury	mg/kg	0.055	<0.05	<0.05	<0.05	0.074	0.079	<0.05	0.07	0.06	<0.05	<0.05	0.053	-
Molybdenum	mg/kg	1.0	1.0	0.67	0.82	0.81	1.4	<0.4	<0.4	0.86	<0.4	<0.4	<0.4	-
Nickel	mg/kg	13	13	12	12	14	23	7.1	<1.0	21	2.6	<1.0	1.1	-
Potassium	mg/kg	490	440	505	533	620	400	600	< 25	68	170	66	37	-
Selenium	mg/kg	1.0	1.1	0.74	0.69	0.77	0.84	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-
Silver	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.1	<0.2	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2	-
Sodium	mg/kg	290	320	270	250	246	250	< 50	< 50	< 50	< 50	< 50	< 50	-
Strontium	mg/kg	41	38	38	35	42	38	23	<10	<10	13	<10	<10	-
Thallium	mg/kg	<0.05	<0.05	<0.05	0.051	0.053	<0.1	<0.3	<0.3	<0.1	<0.1	<0.1	<0.1	-
Titanium	mg/kg	46	50	38	32	42	37	70	6.2	7.5	17	12	14	-
Uranium	mg/kg	0.81	0.67	0.43	0.51	0.48	0.64	<1.0	<1.0	<0.2	0.27	<0.2	<0.2	-
Vanadium	mg/kg	11	14	11	10	11	9.2	12	1.4	<1.0	4.1	1.5	1.7	-
Zinc	mg/kg	78	80	70	65	68	76	12	<10	<10	<10	<10	<10	-
Target PAHs and Alkylated PAHs														
Acenaphthene	mg/kg	0.0056	0.0038	0.0045	0.004	0.0032	<0.0066	**0.0069**[l]	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
C1 substituted acenaphthene	mg/kg	<0.00054	<0.00095	0.0011	<0.00047	<0.0013	<0.067	0.05	<0.005	<0.005	<0.005	<0.005	<0.005	-
Acenaphthylene	mg/kg	<0.00071	<0.00071	0.00071	<0.00052	<0.00048	<0.0066	<0.0018	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Anthracene	mg/kg	0.003	0.0036	0.0013	0.0021	0.0016	<0.0066	<0.0028	<0.0005	<0.0005	<0.0005	0.00074	0.0013	-
Dibenzo(a,h)anthracene	mg/kg	<0.0017	<0.0018	0.0015	<0.0015	<0.0022	<0.013[DL>l]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Benzo(a)anthracene	mg/kg	0.0019	0.0024	0.0029	0.00089	0.0014	<0.0066	<0.0005	<0.0005	0.0018	<0.0005	<0.0005	<0.0005	-
Benzo(c)phenanthrene	mg/kg	-	-	-	-	-	<0.066	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
C1 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	0.017	0.0059	0.023	0.011	0.004	<0.067	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted benzo(bjk)fluoranthene / benzo(a)pyrene	mg/kg	0.011	0.071	0.013	0.0036	<0.0024	<0.067	<0.005	<0.005	<0.005	<0.005	<0.005	0.0093	-
Biphenyl	mg/kg	0.0093	0.0076	0.0087	0.0057	0.0056	<0.067	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
C1 substituted biphenyl	mg/kg	0.0039	0.0041	0.0029	0.0021	0.0013	<0.067	0.033	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted biphenyl	mg/kg	0.03	0.012	0.01	0.004	0.002	<0.067	0.1	<0.005	<0.005	<0.005	<0.005	<0.005	-
Chrysene	mg/kg	0.0053	0.0036	0.0047	0.0037	0.0033	<0.0066	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
C1 substituted benzo(a)anthracene / chrysene	mg/kg	0.016	0.011	0.02	0.011	0.016	<0.067	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted benzo(a)anthracene / chrysene	mg/kg	0.029	0.011	0.022	0.011	0.02	<0.067	0.019	0.014	0.012	0.011	0.0084	0.013	-
C3 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	-	-	0.035	<0.067	<0.005	0.0092	<0.005	<0.005	<0.005	0.012	-
C4 substituted benzo(a)anthracene / chrysene	mg/kg	-	-	-	-	0.021	<0.067	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	-
Dibenzothiophene	mg/kg	0.0027	0.0043	0.0056	0.0019	0.0018	<0.067	0.025	<0.005	<0.005	<0.005	<0.005	<0.005	-
C1 substituted dibenzothiophene	mg/kg	0.0029	0.0073	0.012	0.0051	0.007	<0.067	0.061	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted dibenzothiophene	mg/kg	0.015	0.0029	0.023	0.0067	0.013	<0.067	0.11	<0.005	0.0054	<0.005	0.011	0.011	-
C3 substituted dibenzothiophene	mg/kg	0.0097	0.018	0.024	0.0075	0.013	<0.067	0.066	<0.005	0.0052	<0.005	<0.005	0.011	-
C4 substituted dibenzothiophene	mg/kg	0.014	0.017	0.022	0.0044	0.0035	<0.067	0.032	<0.005	<0.005	<0.005	0.015	<0.005	-
Fluoranthene	mg/kg	0.014	0.013	0.011	0.01	0.0079	0.0081	0.00099	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Benzo(b,j,k)fluoranthene[a]	mg/kg	0.0054	0.0066	0.0046	<0.0011	-	-	-	-	-	-	-	-	-
Benzo(b,j)fluoranthene	mg/kg	-	-	-	-	-	<0.0066	<0.0014	<0.001	<0.0005	0.0017	0.00074	0.0015	-
Benzo(k)fluoranthene	mg/kg	-	-	-	-	-	<0.0066	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Fluorene	mg/kg	0.021	0.00099	0.015	0.015	0.012	0.0081	**0.023**[l]	<0.0005	0.00056	0.0027	0.0025	<0.0005	-
C1 substituted fluorene	mg/kg	0.034	0.03	0.032	0.016	0.014	<0.067	0.22	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted fluorene	mg/kg	0.041	0.042	0.027	0.02	0.014	<0.067	0.22	<0.005	<0.005	<0.005	<0.005	<0.005	-
C3 substituted fluorene	mg/kg	0.034	0.026	0.02	0.011	0.0091	<0.067	0.27	<0.005	<0.005	<0.005	<0.005	<0.005	-
Naphthalene	mg/kg	0.019	0.0083	0.014	0.0065	0.0079	<0.0066	0.0066	<0.0005	<0.0005	<0.0005	0.001	<0.0005	-
1-Methylnaphthalene	mg/kg	-	-	-	-	0.0027	<0.067	0.069	<0.005	<0.005	<0.005	<0.005	<0.005	-
2-Methylnaphthalene	mg/kg	-	-	-	-	0.0039	<0.066	0.085	<0.005	<0.005	<0.005	<0.005	<0.005	-
C1 substituted naphthalene	mg/kg	0.01	0.0085	0.013	0.0044	0.0063	<0.067	0.16	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted naphthalene	mg/kg	0.17	0.059	0.037	0.069	0.099	0.26	0.98	<0.005	<0.005	<0.005	0.023	0.013	-
C3 substituted naphthalene	mg/kg	0.042	0.024	0.024	0.02	0.011	<0.067	0.86	<0.005	<0.005	<0.005	<0.005	<0.005	-
C4 substituted naphthalene	mg/kg	0.029	0.0056	0.018	0.012	0.0046	<0.067	0.56	<0.005	<0.005	<0.005	<0.005	<0.005	-
Perylene	mg/kg	-	-	-	-	0.016	<0.066	<0.005	<0.005	0.0067	<0.005	<0.005	<0.005	-
Benzo(g,h,i)perylene	mg/kg	0.0053	0.0058	0.0056	0.003	0.0038	<0.013	<0.0023	<0.001	<0.001	<0.001	<0.001	<0.001	-
Phenanthrene	mg/kg	0.029	0.026	0.027	0.023	0.016	0.011	0.041	<0.0005	<0.0005	0.00084	0.00089	<0.0005	-
C1 substituted phenanthrene / anthracene	mg/kg	0.025	0.018	0.023	0.021	0.016	<0.067	0.14	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted phenanthrene / anthracene	mg/kg	0.025	0.029	0.028	0.023	0.015	<0.067	0.17	<0.005	<0.005	<0.005	<0.005	<0.005	-
C3 substituted phenanthrene / anthracene	mg/kg	0.04	0.037	0.036	0.029	0.019	<0.067	0.13	<0.005	0.0057	0.01	0.019	0.014	-
C4 substituted phenanthrene / anthracene	mg/kg	0.13	0.12	0.12	0.079	0.052	<0.067	0.058	<0.005	0.009	0.022	0.052	0.02	-
Pyrene	mg/kg	0.0089	0.0083	0.0076	0.007	0.0055	<0.0066	0.0023	0.00069	0.00075	0.0012	<0.0005	0.00072	-
C1 substituted fluoranthene / pyrene	mg/kg	0.036	0.028	0.035	0.023	0.019	<0.067	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	-
C2 substituted fluoranthene / pyrene	mg/kg	0.036	0.03	0.034	0.018	0.015	<0.067	0.025	0.006	0.0085	<0.005	0.011	0.013	-
C3 substituted fluoranthene / pyrene	mg/kg	0.0079	0.012	0.018	0.0078	<0.003	<0.067	0.018	0.015	0.018	0.013	0.011	0.032	-
C4 substituted fluoranthene / pyrene	mg/kg	-	-	-	-	0.011	<0.067	0.033	0.0091	0.01	<0.005	0.0099	0.023	-
Indeno(c,d-123)pyrene	mg/kg	0.0074	0.0083	0.0053	0.003	0.0032	<0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
Benzo(a)pyrene	mg/kg	0.0011	<0.0014	0.0029	<0.0014	<0.0015	<0.0066	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	-
Benzo(e)pyrene	mg/kg	-	-	-	-	0.0024	<0.066	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
Retene	mg/kg	0.049	0.042	0.041	0.035	0.022	<0.067	0.028	<0.005	0.012	0.044	0.056	0.019	-
PANHs														
Quinoline	mg/kg	-	-	-	-	-	<0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Acridine	mg/kg	-	-	-	-	-	<0.13	0.029	<0.01	<0.01	<0.01	<0.01	<0.01	-

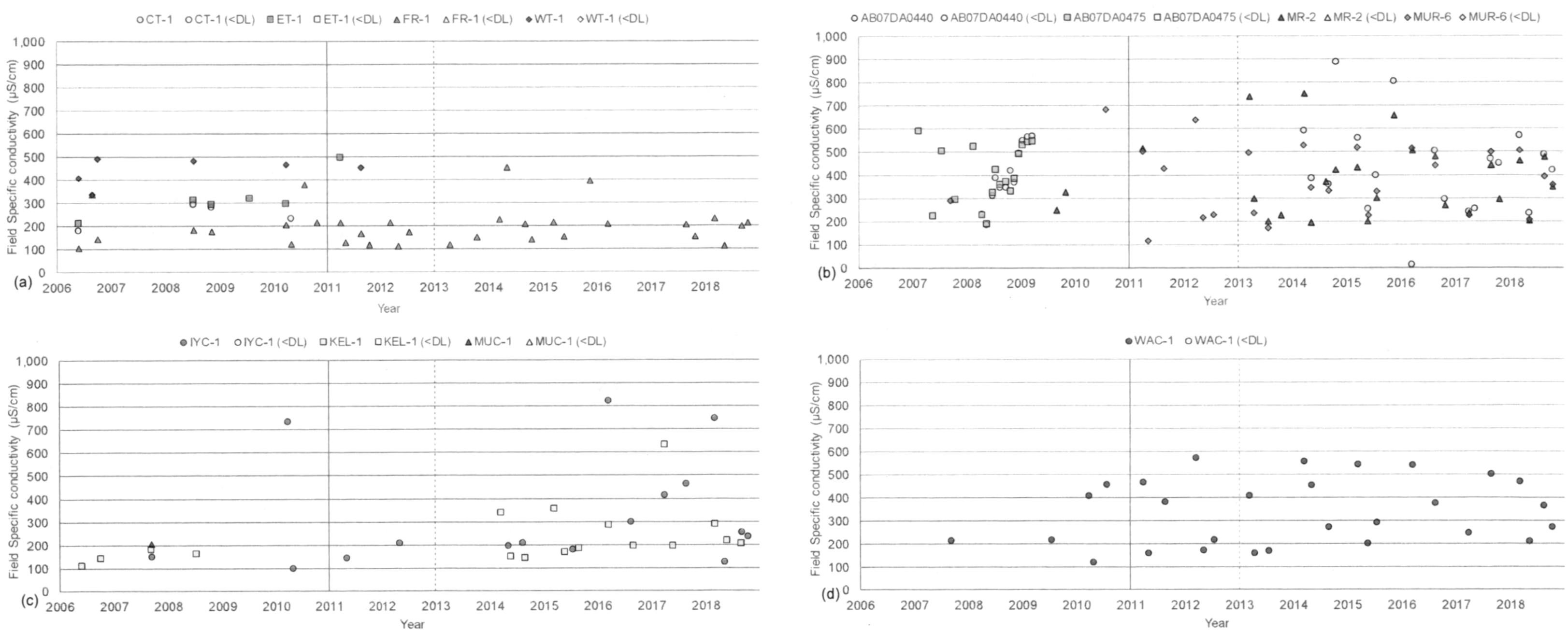
APPENDIX VII

Time Series Plots for Water Quality Parameters



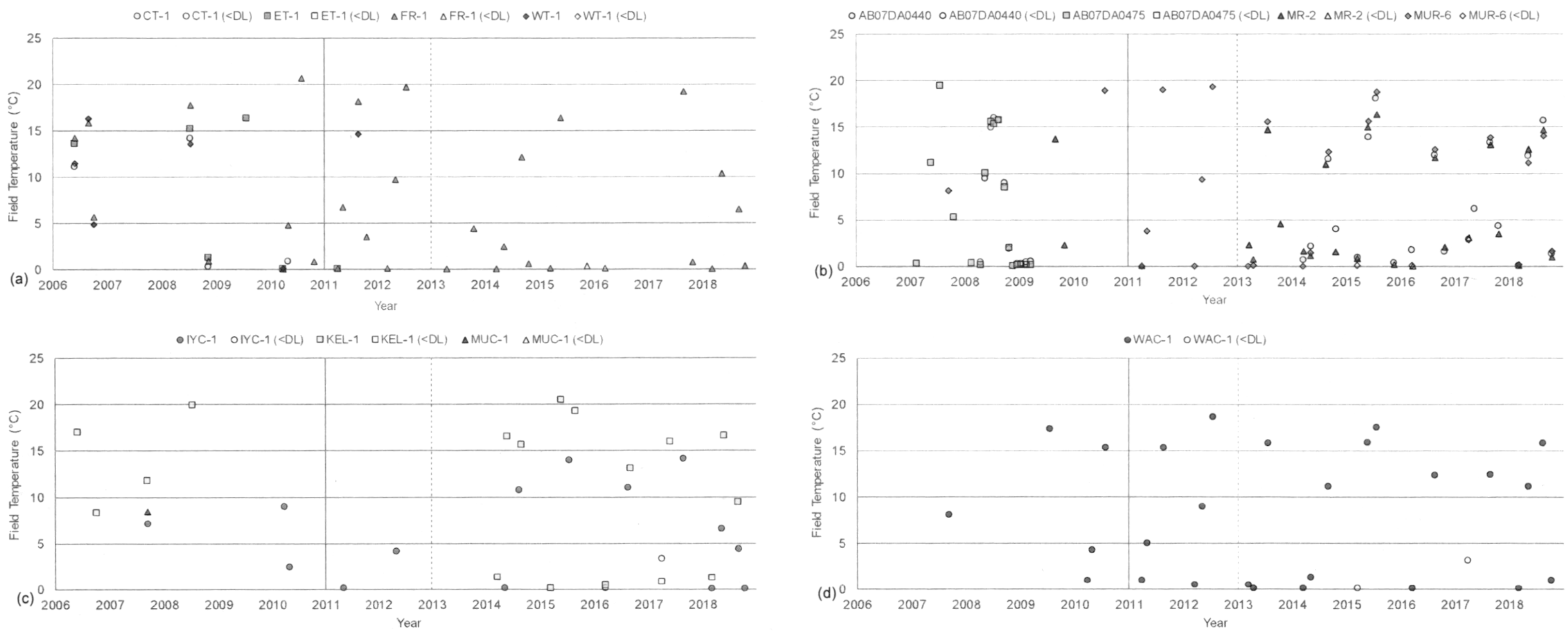
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).

Figure VII-1 Time Series Plots of Field Measured pH



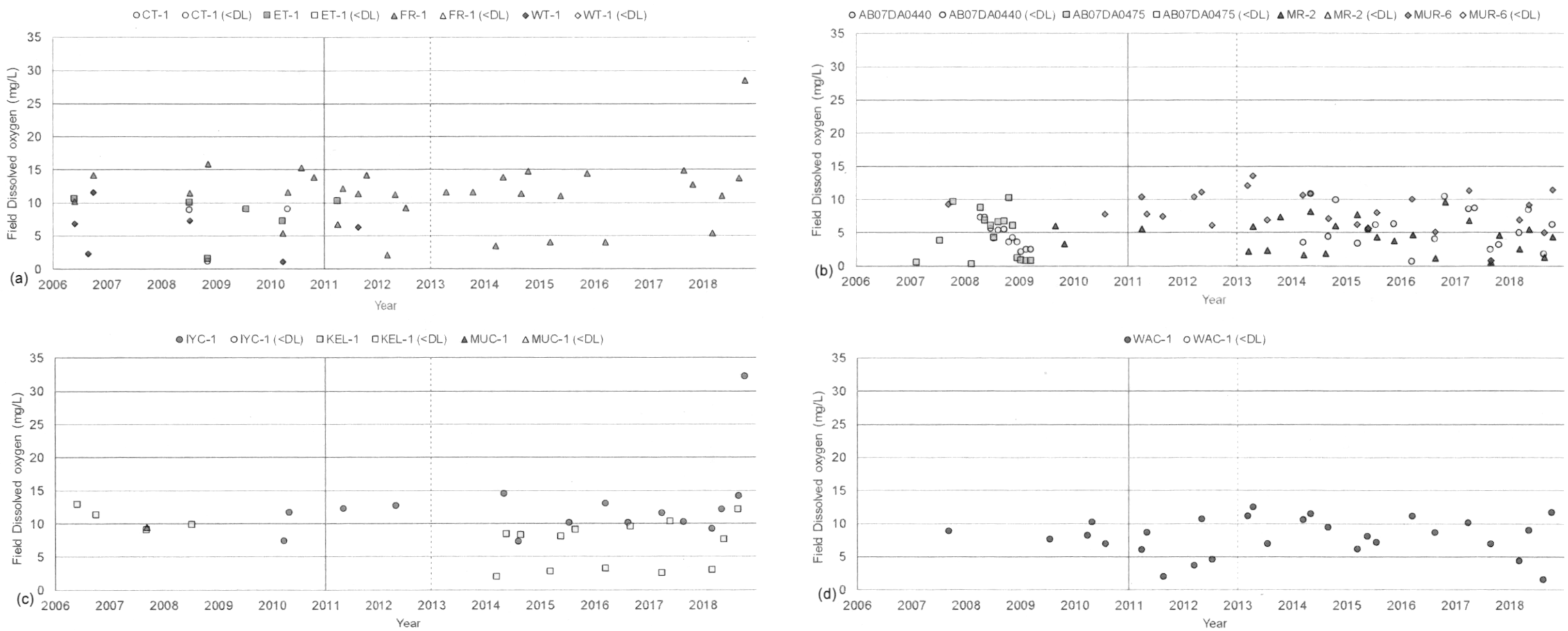
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure VII-2 **Time Series Plots of Field Measured Specific Conductivity**



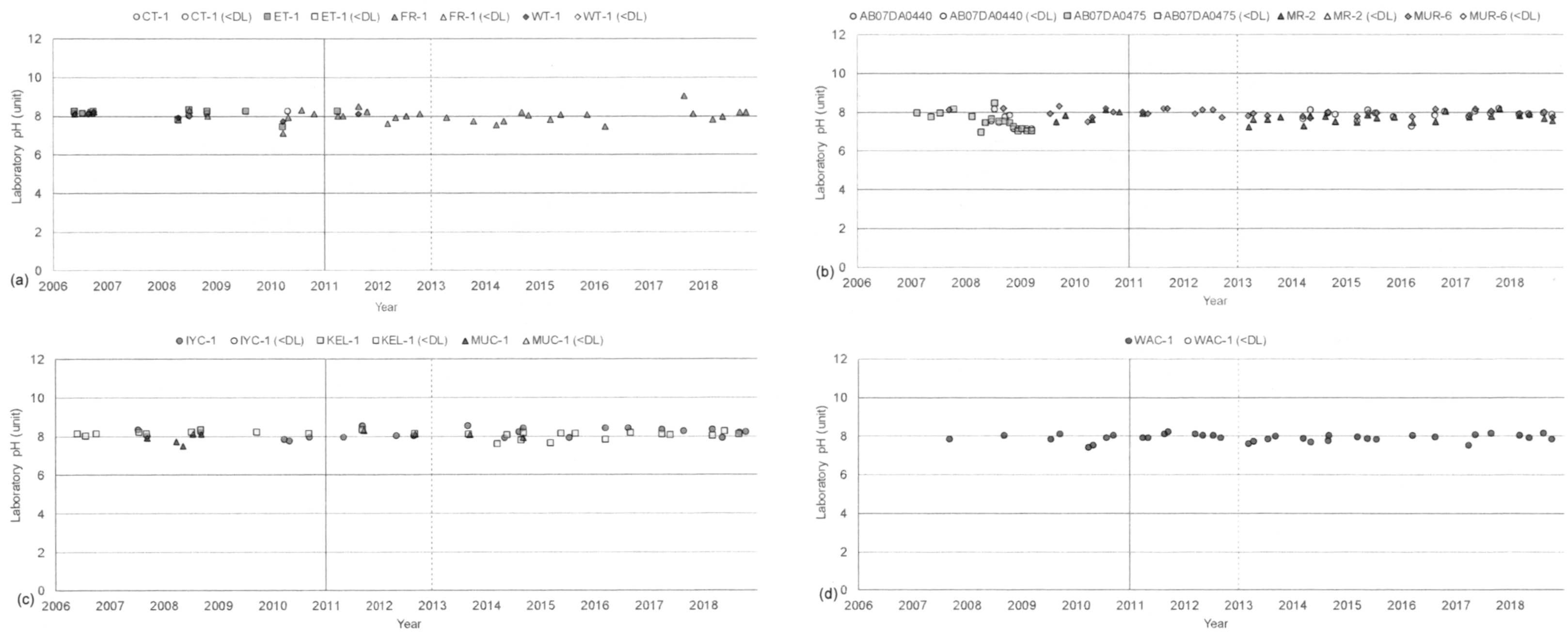
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-3 Time Series Plots of Field Measured Temperature



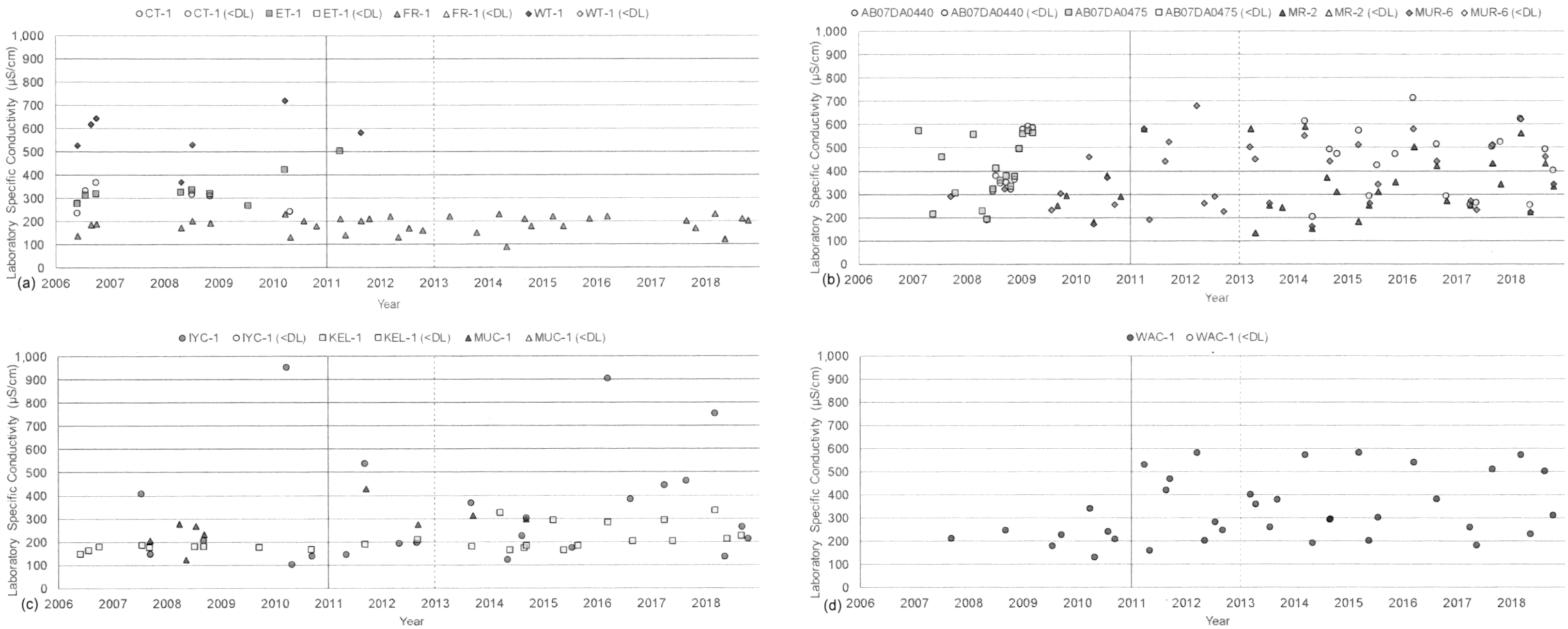
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-4 **Time Series Plots of Field Measured Dissolved Oxygen**



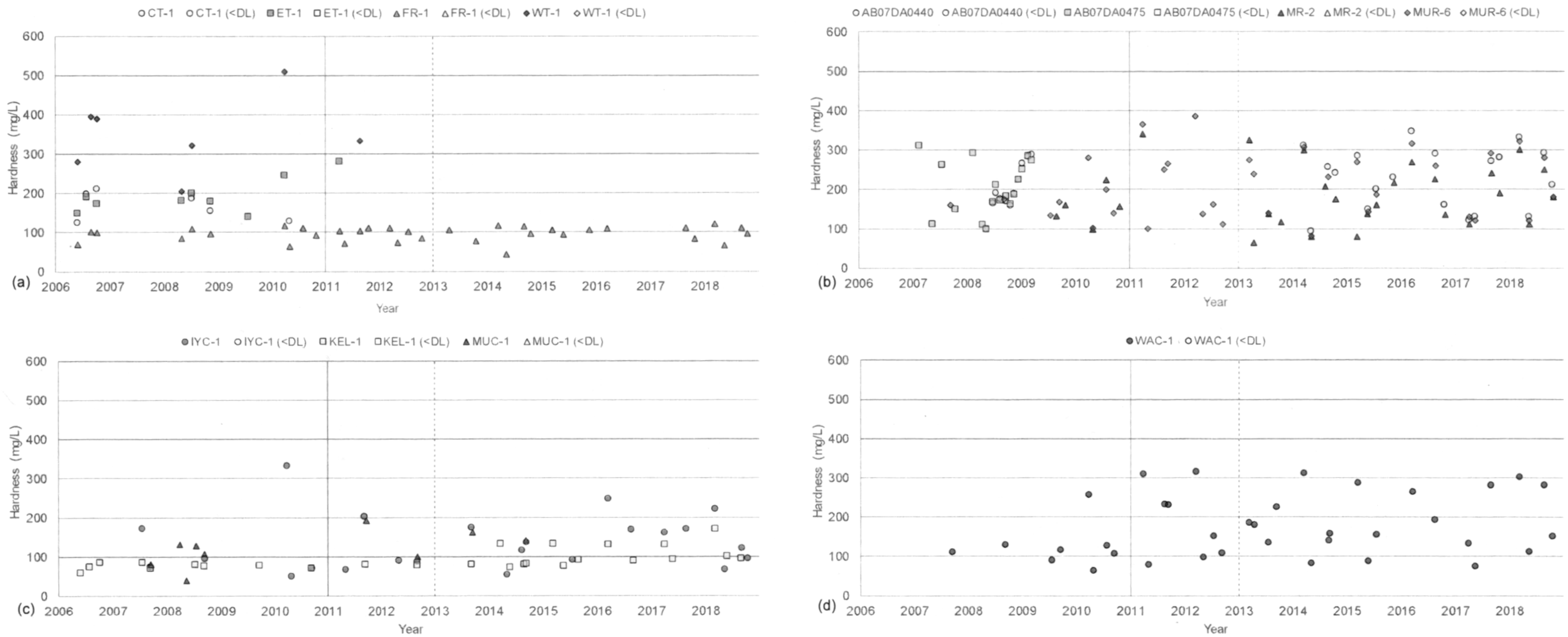
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).

Figure VII-5 **Time Series Plots of Laboratory pH**



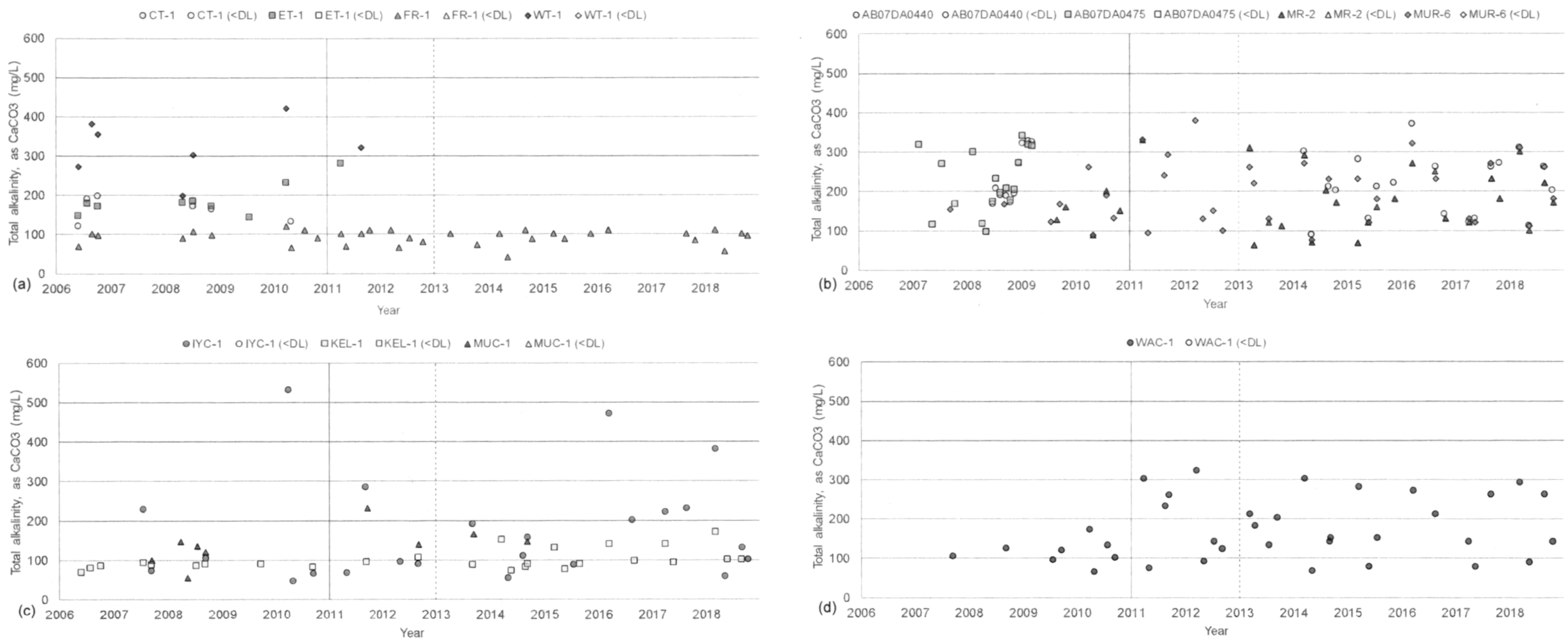
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure VII-6 **Time Series Plots of Laboratory Specific Conductivity**



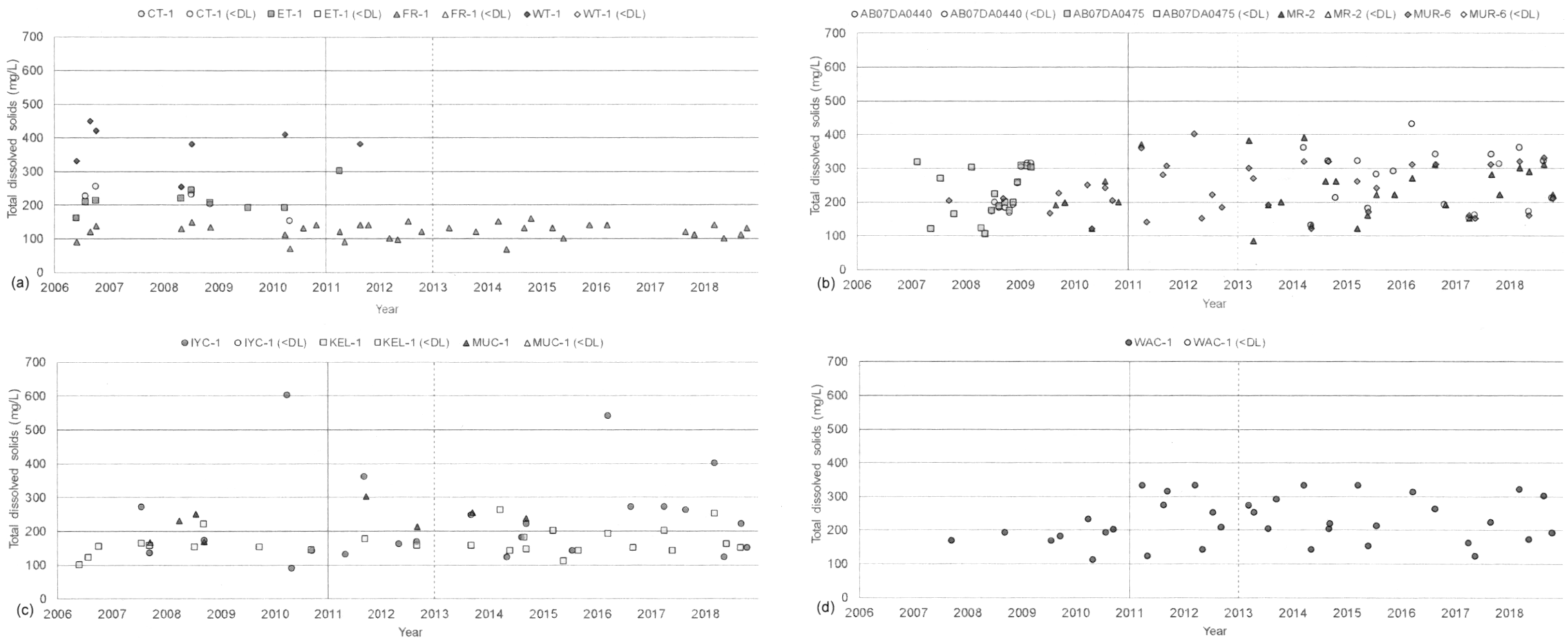
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-7 Time Series Plots of Hardness



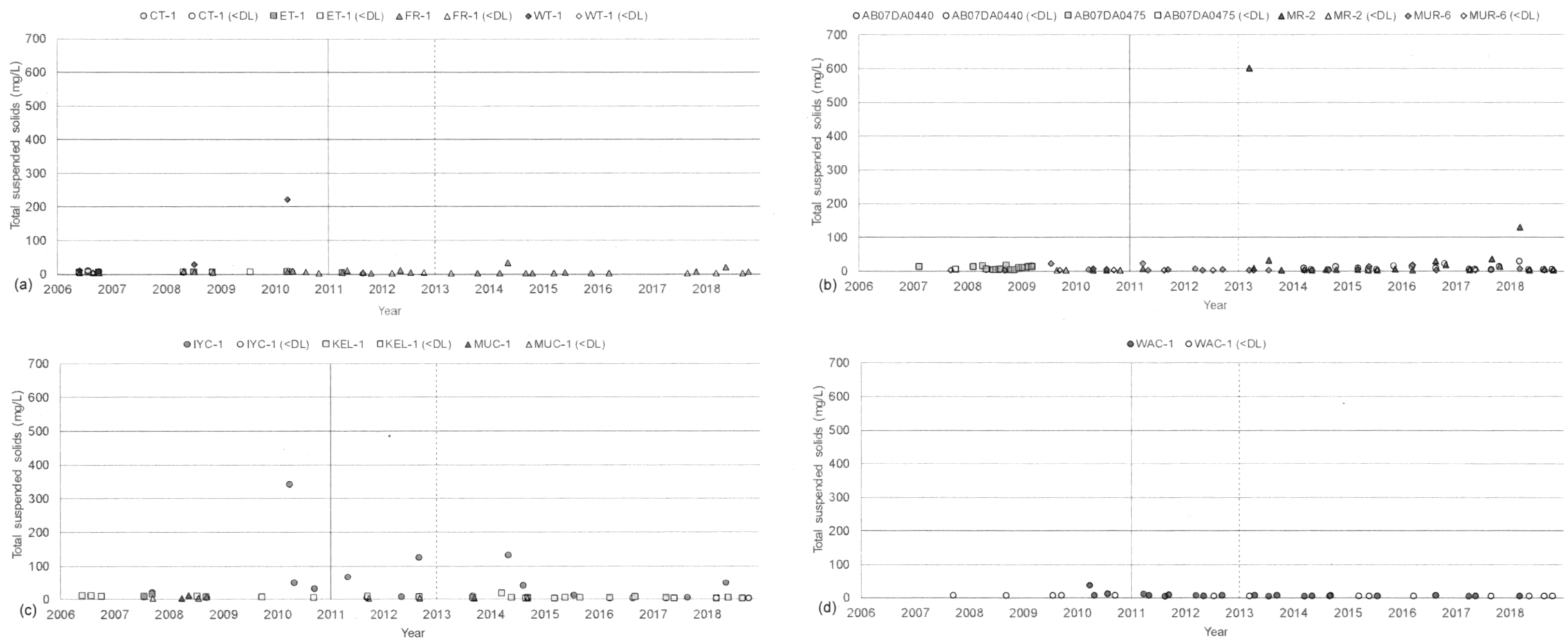
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-8 **Time Series Plots of Total Alkalinity, as $CaCO_3$**



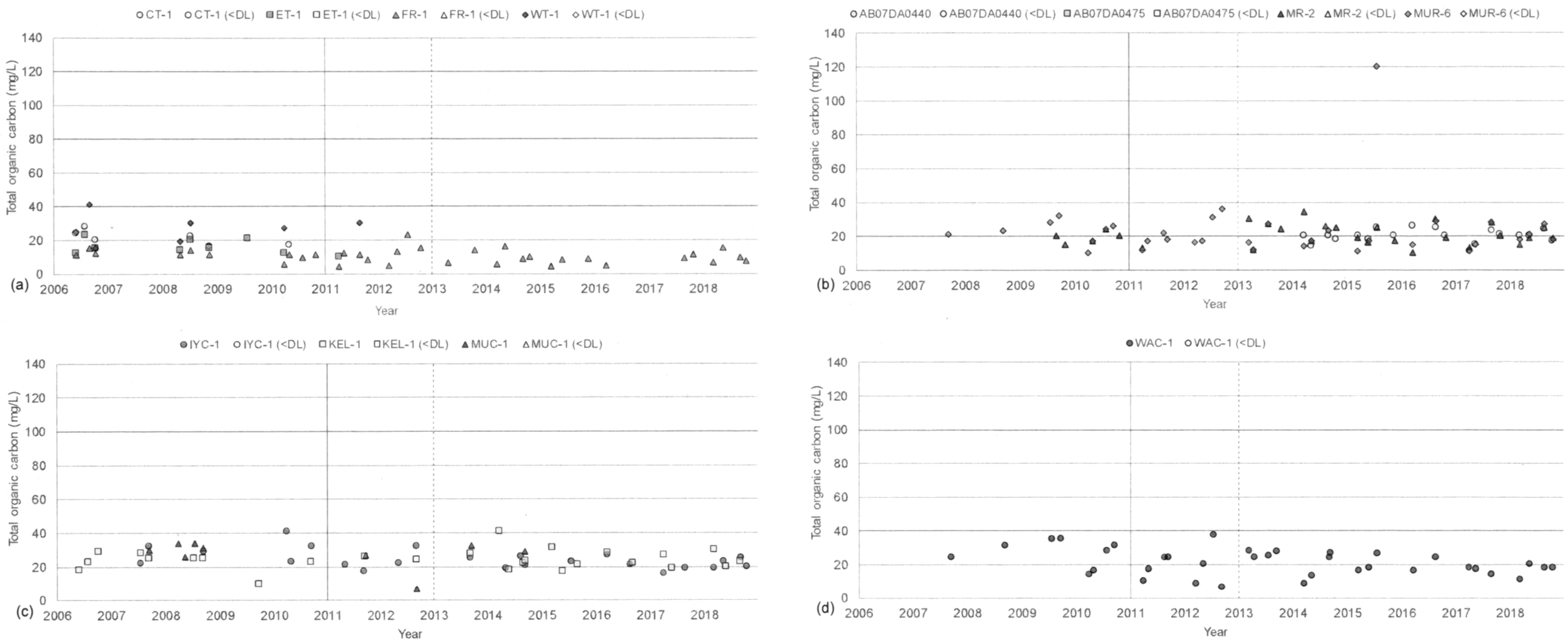
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-9 Time Series Plots of Total Dissolved Solids



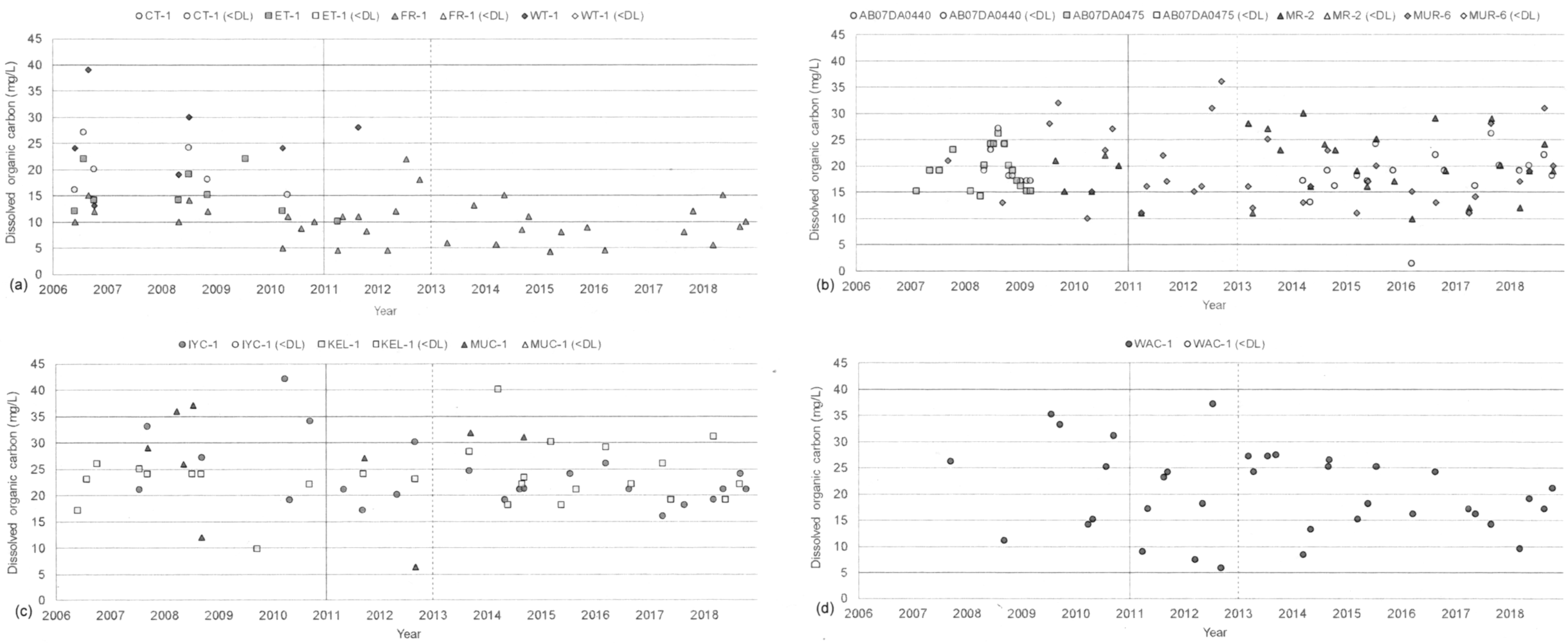
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-10 Time Series Plots of Total Suspended Solids



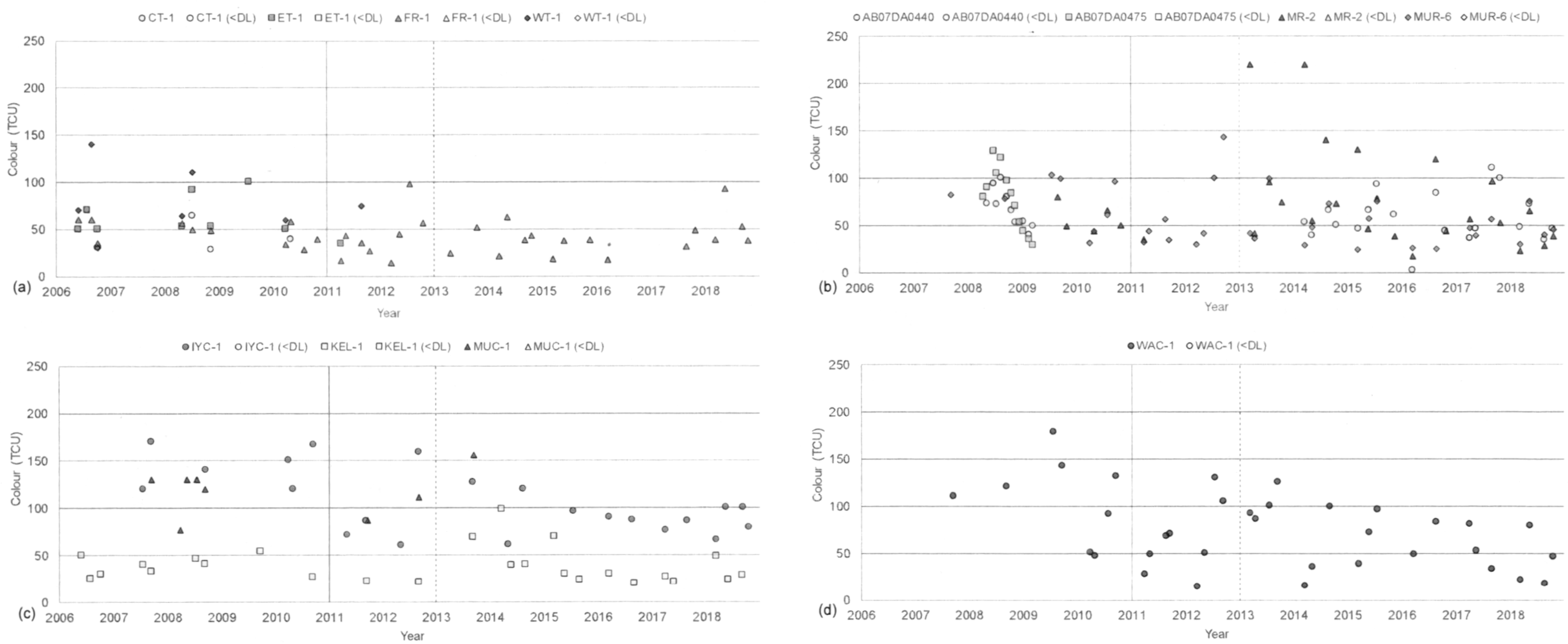
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-11 Time Series Plots of Total Organic Carbon



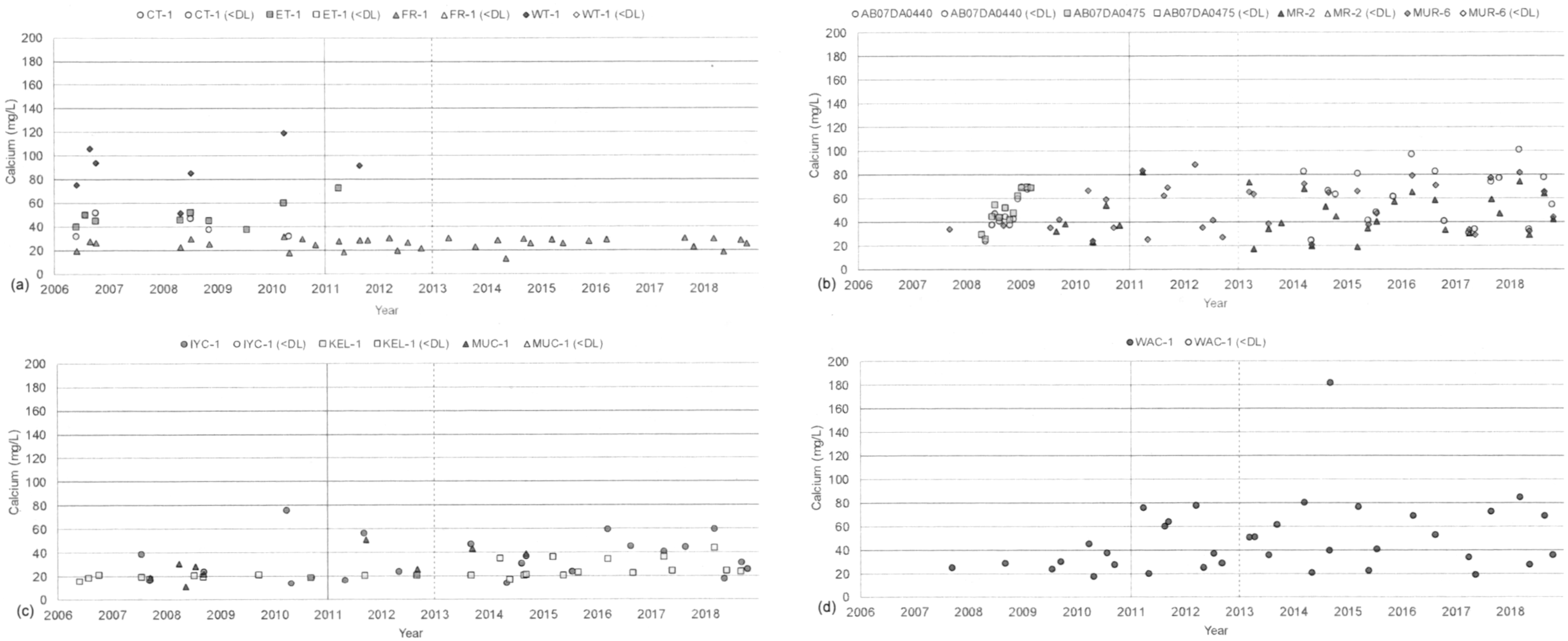
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-12 **Time Series Plots of Dissolved Organic Carbon**



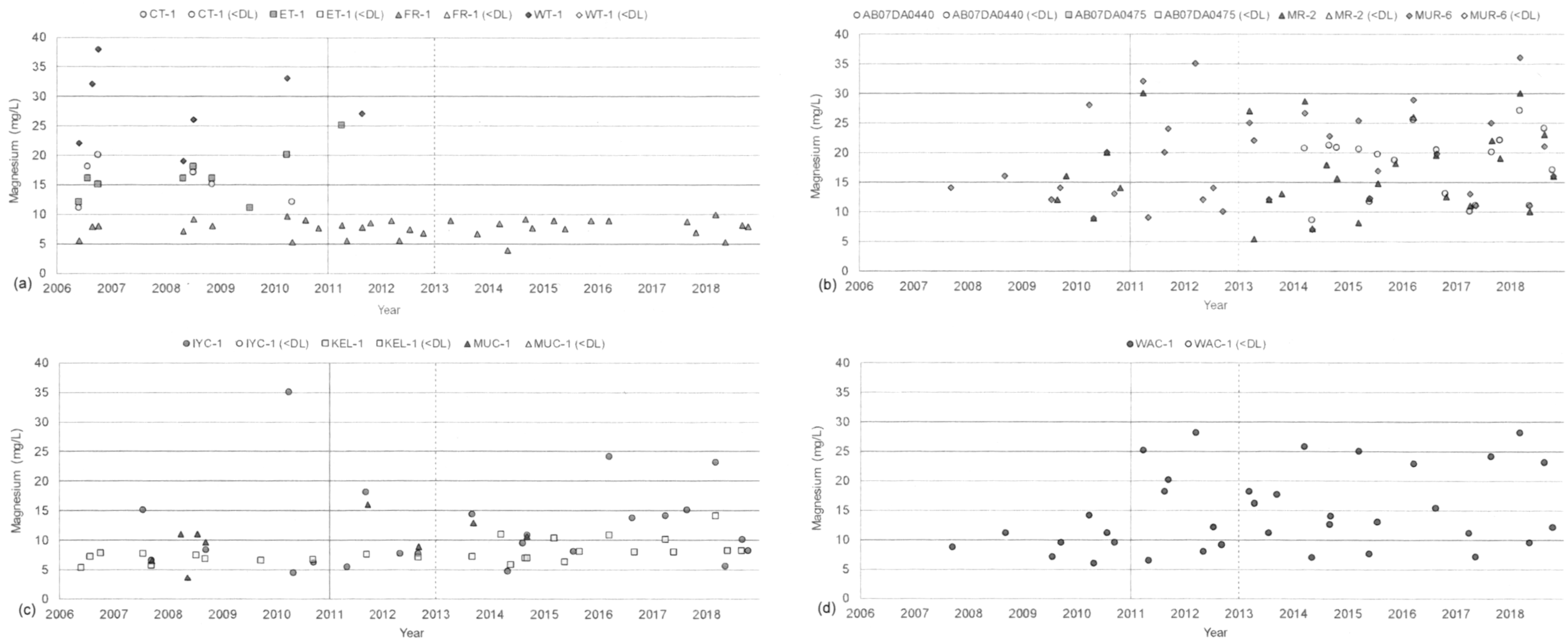
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-13 Time Series Plots of Colour



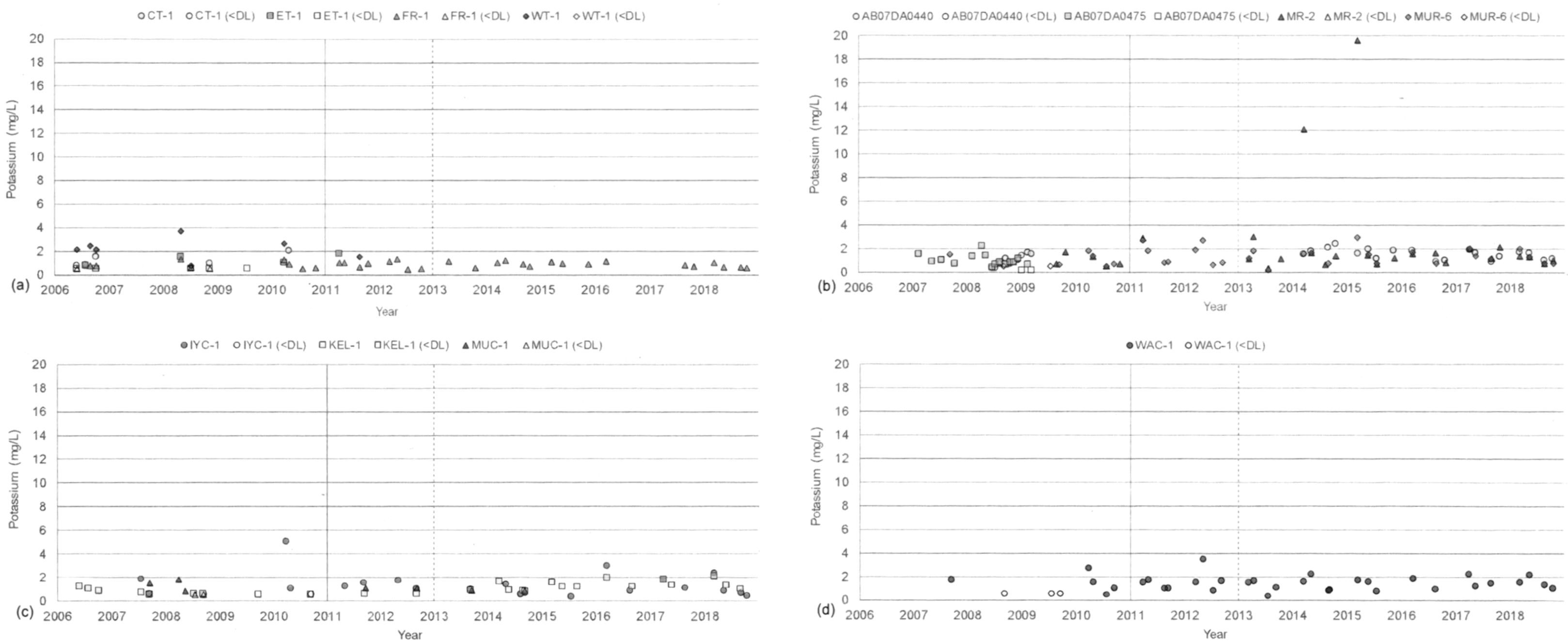
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-14 **Time Series Plots of Calcium**



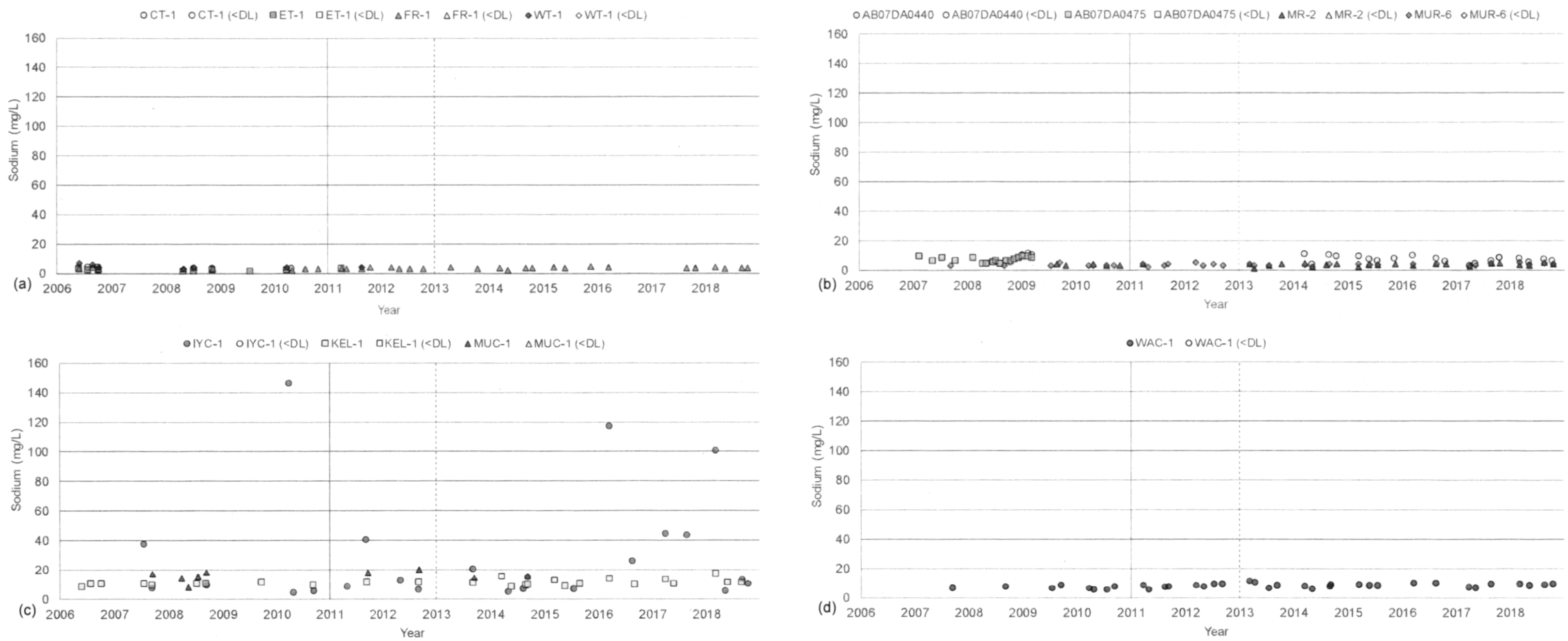
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-15 Time Series Plots of Magnesium



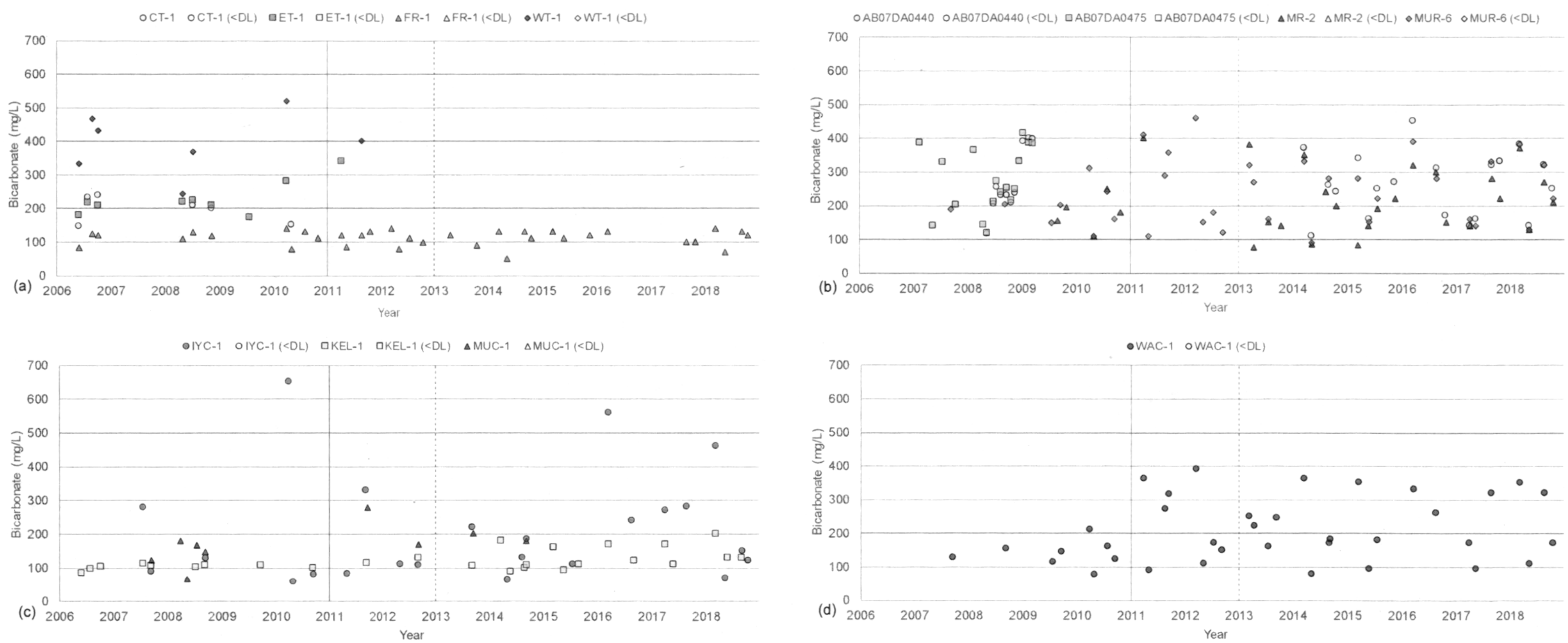
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-16 Time Series Plots of Potassium



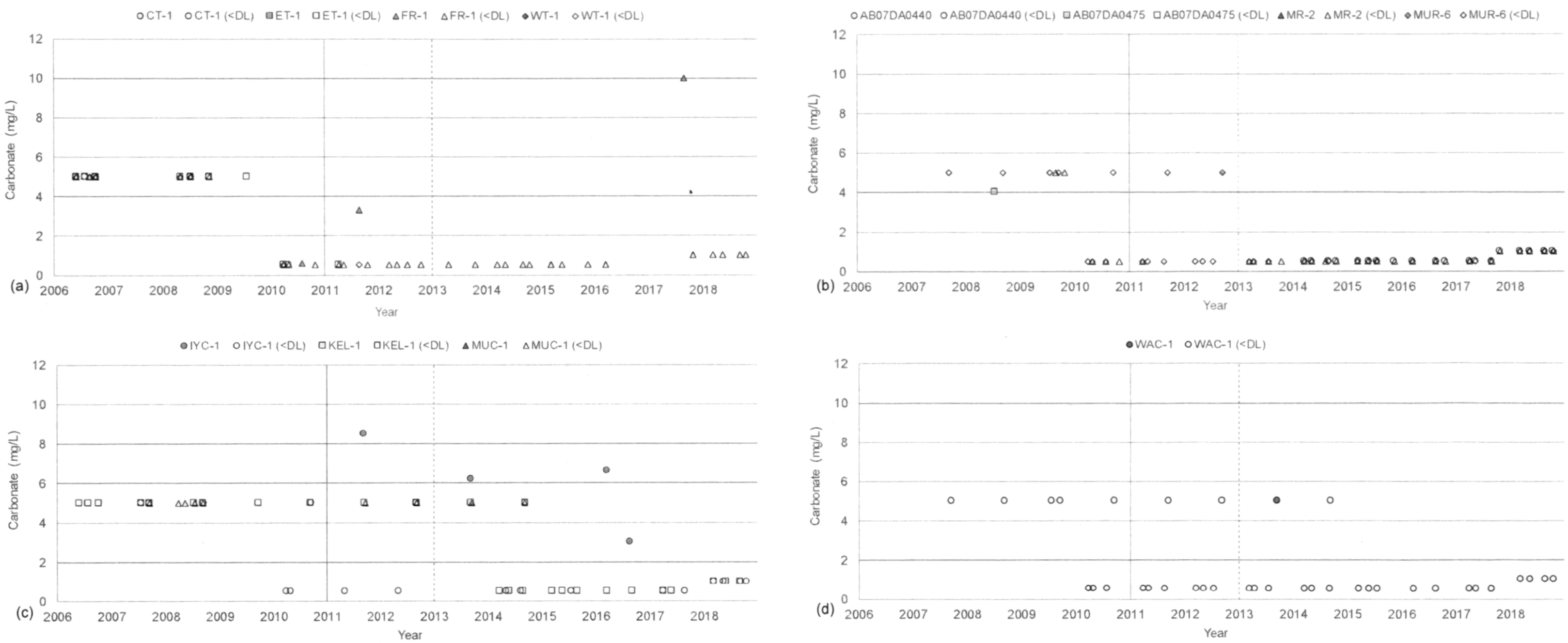
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-17 Time Series Plots of Sodium



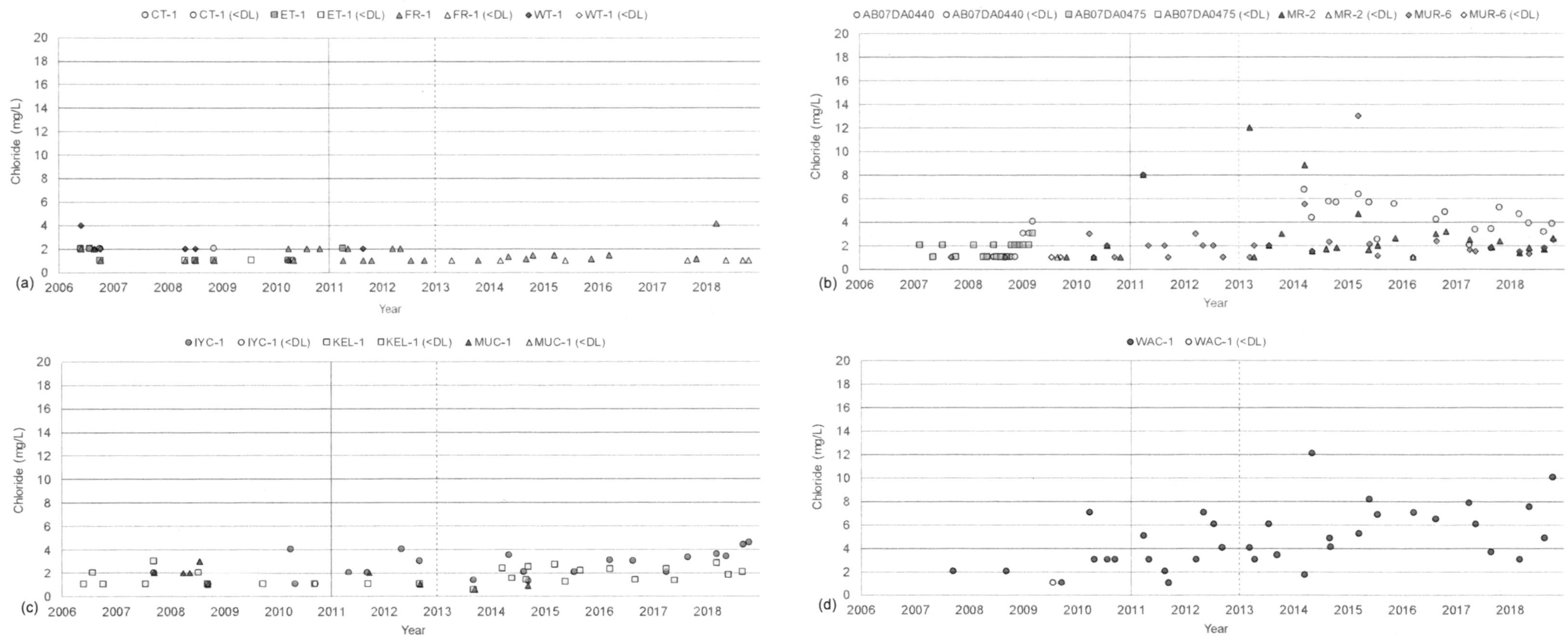
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-18 **Time Series Plots of Bicarbonate**



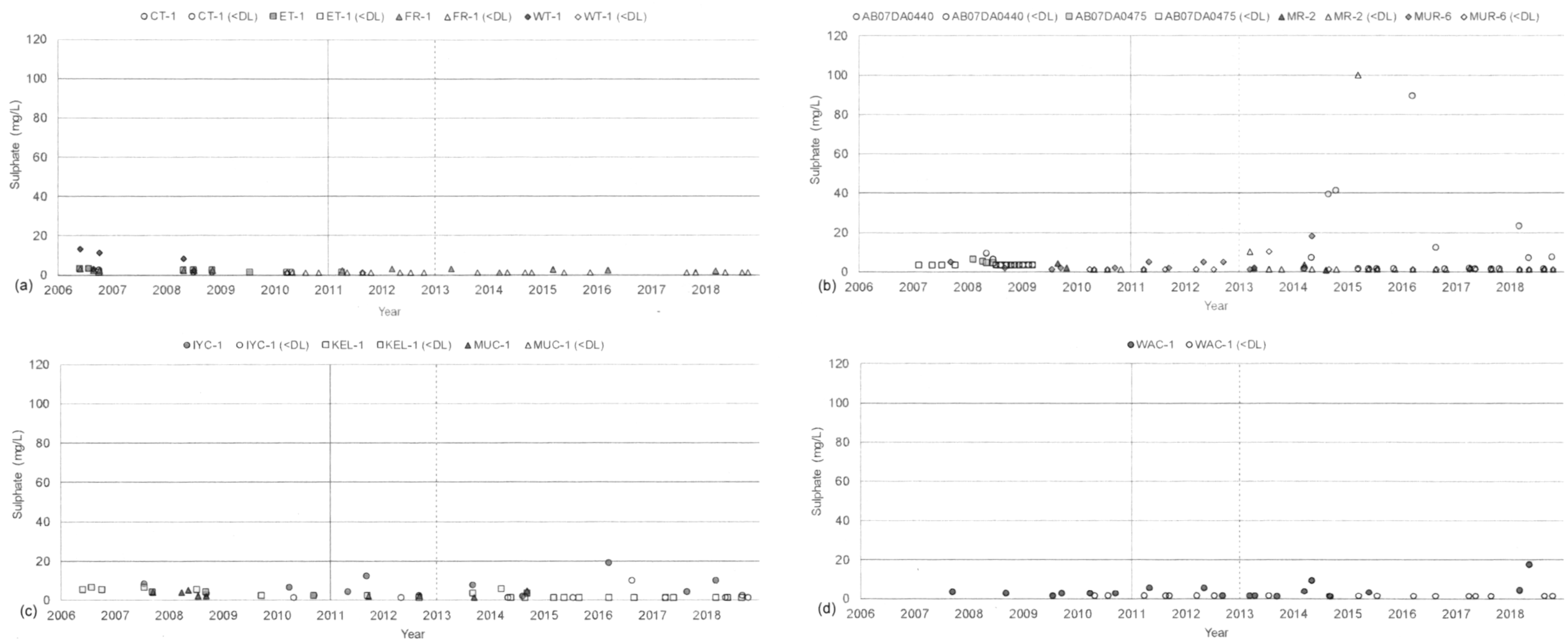
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-19 **Time Series Plots of Carbonate**



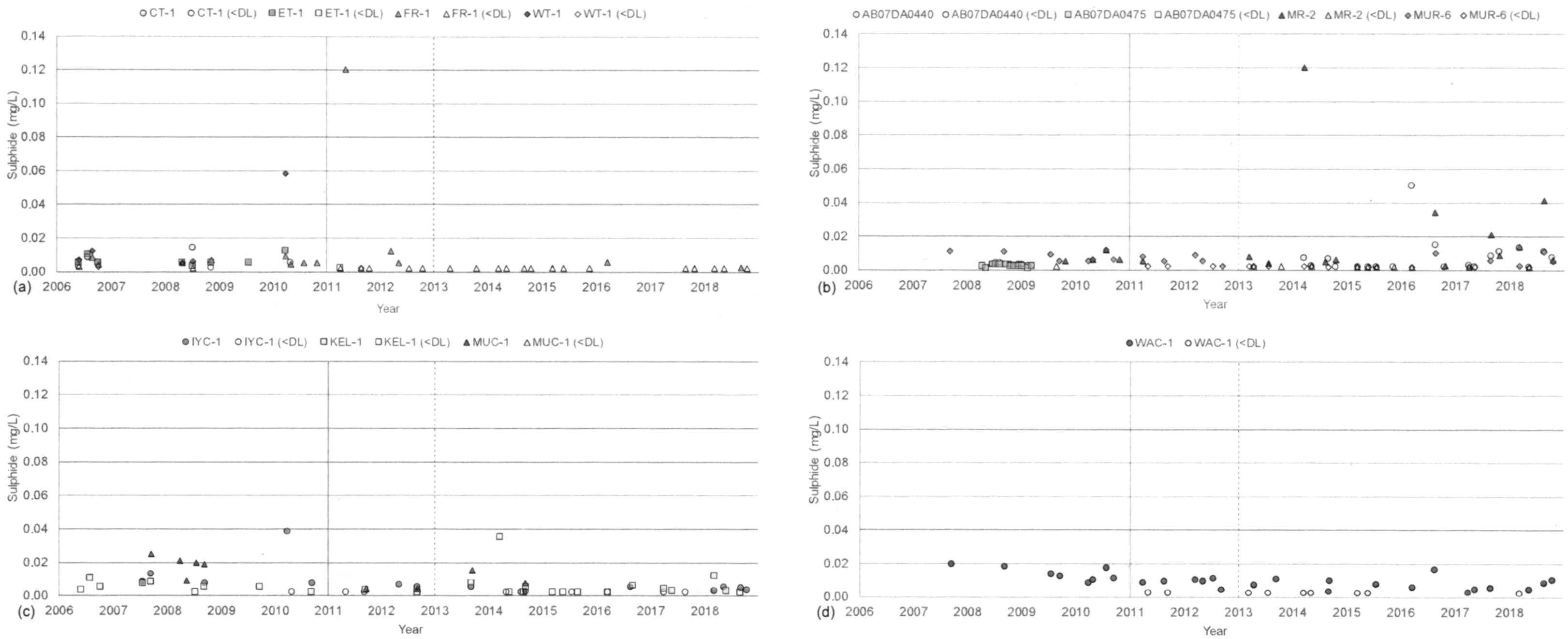
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-20 **Time Series Plots of Chloride**



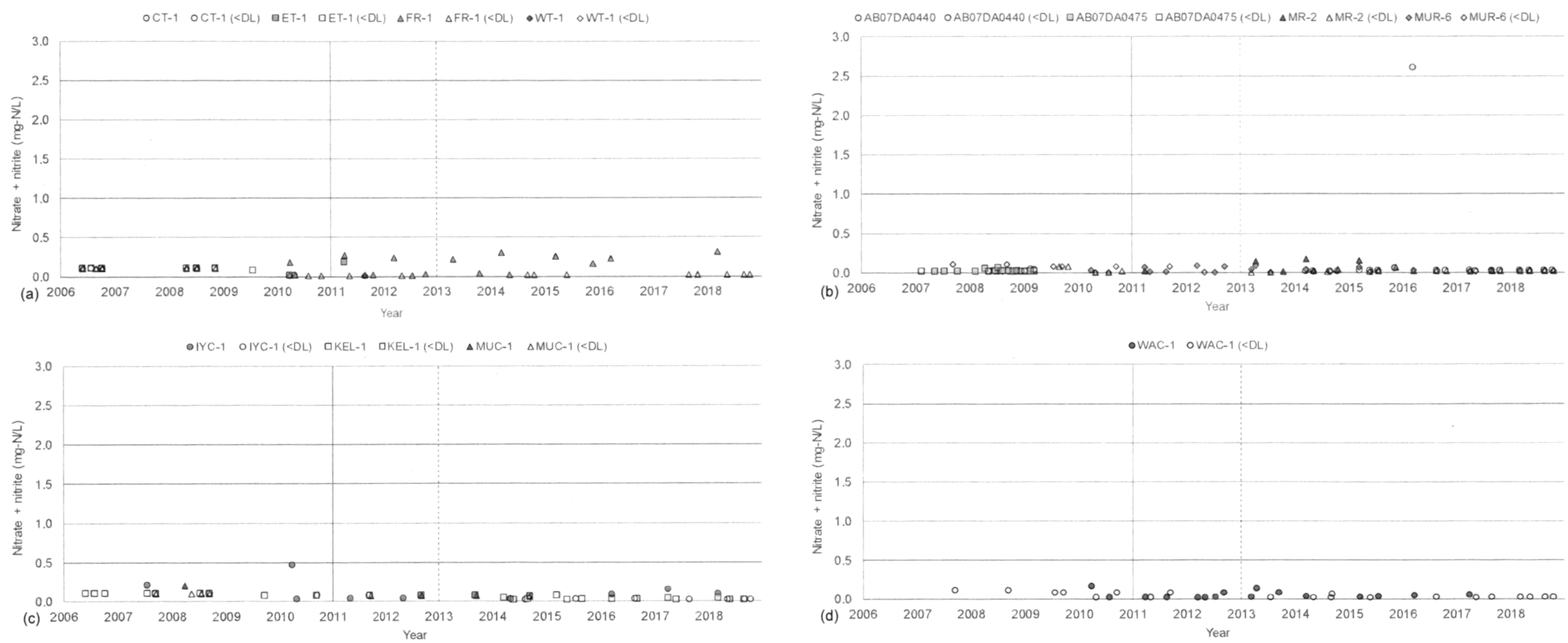
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-21 Time Series Plots of Sulphate



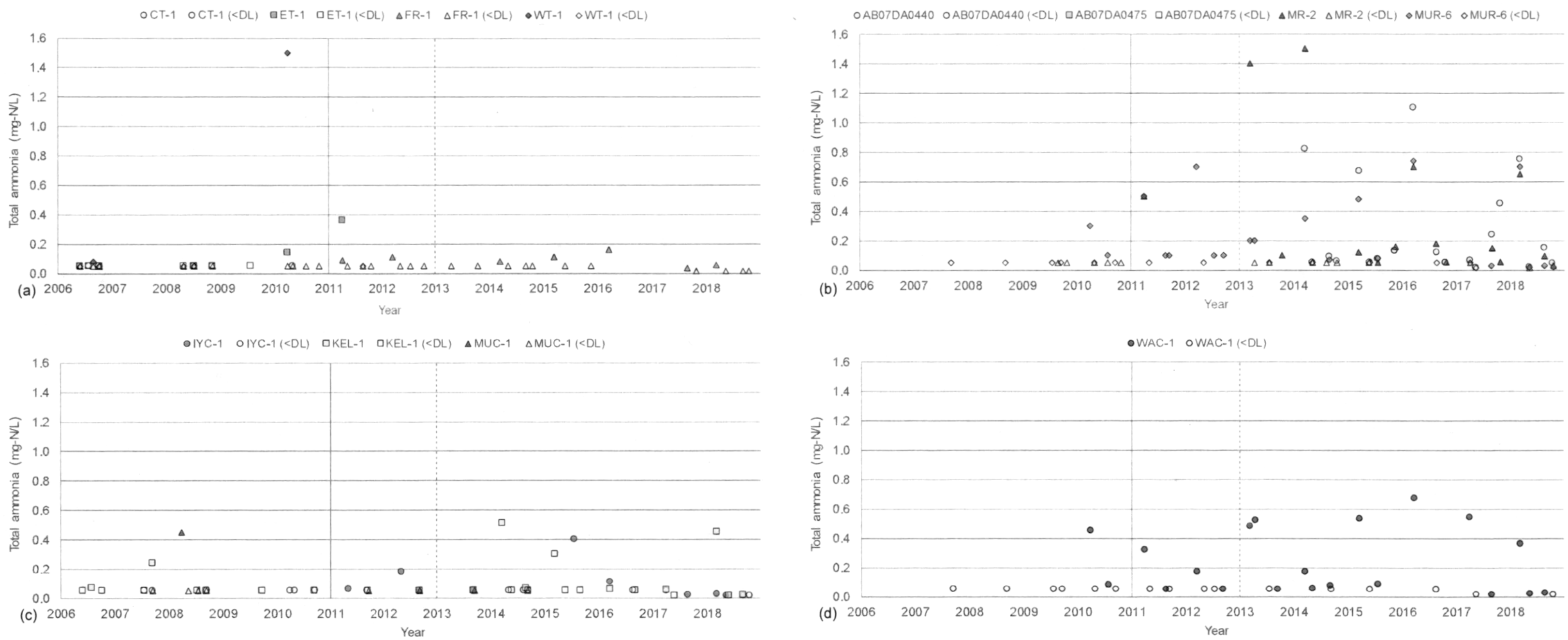
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-22 Time Series Plots of Sulphide



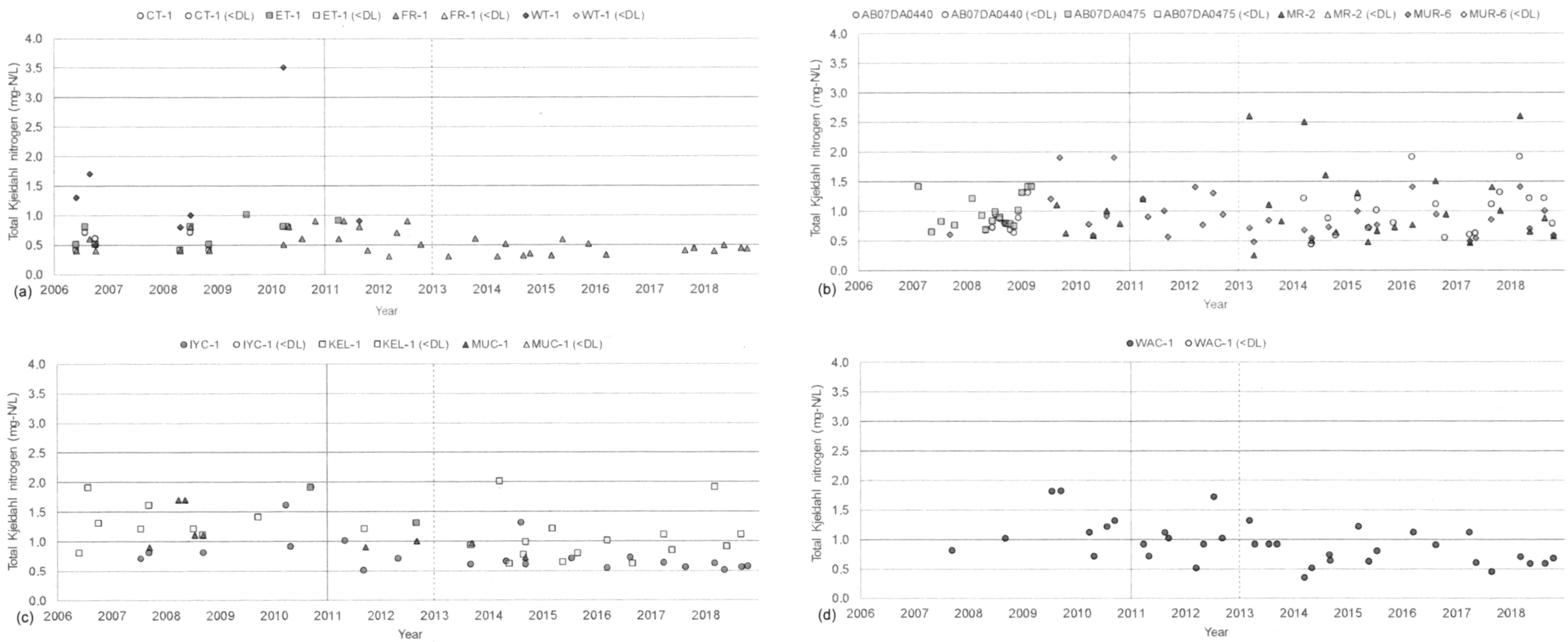
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-23 Time Series Plots of Nitrate + Nitrite



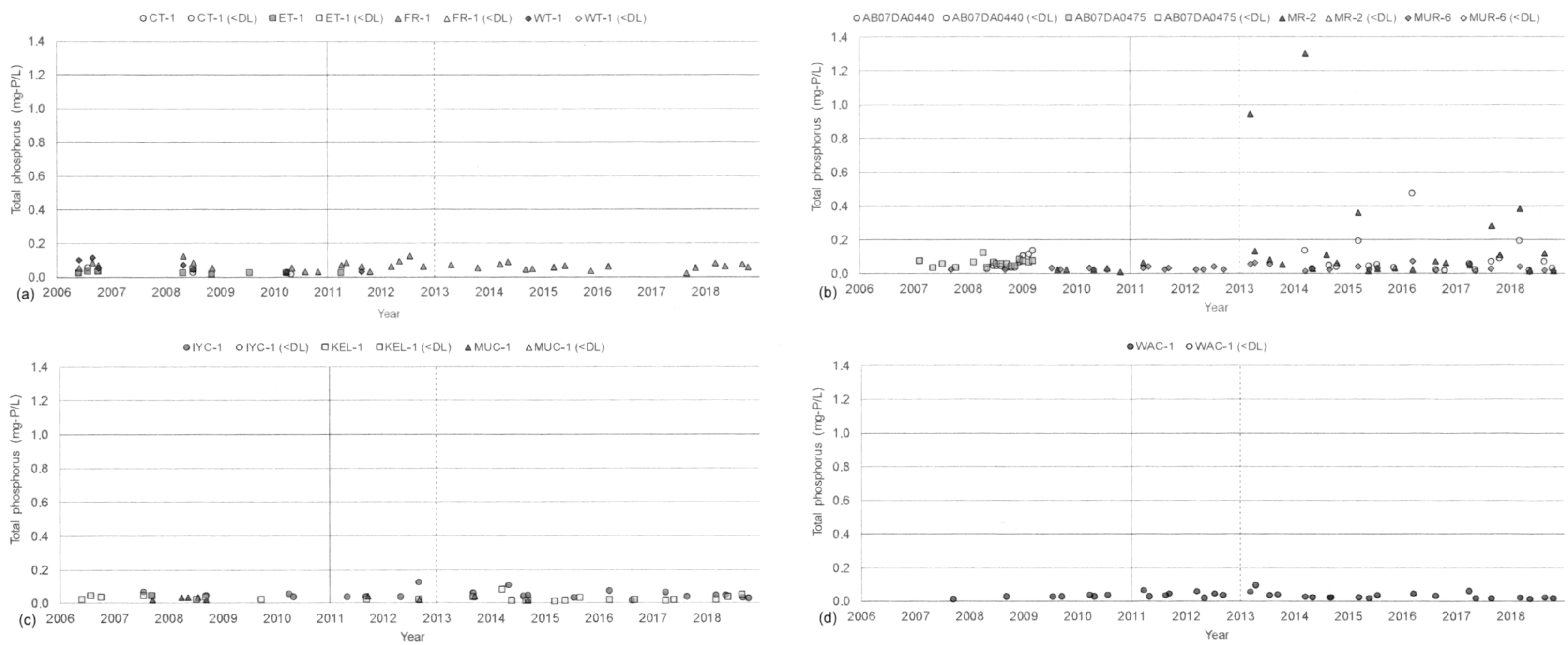
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-24 **Time Series Plots of Total Ammonia**



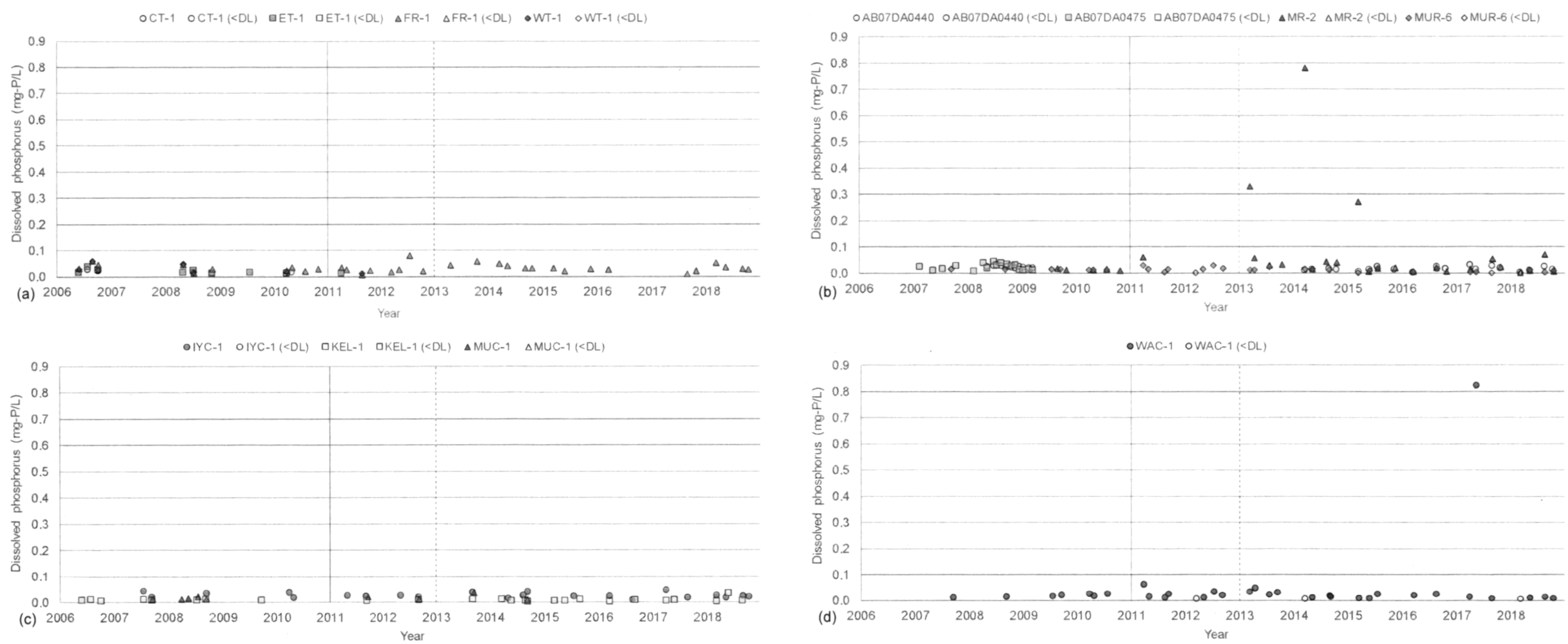
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-25 **Time Series Plots of Total Kjeldahl Nitrogen**



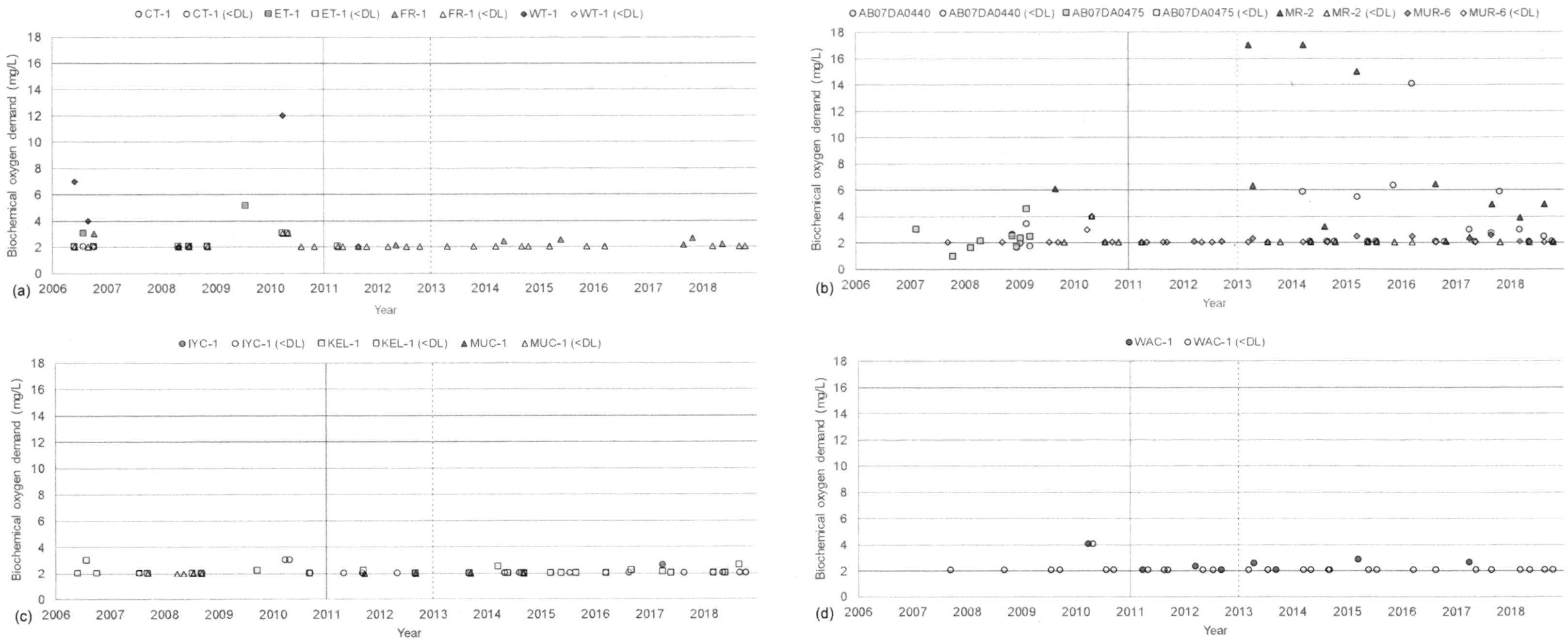
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
mg-P/L = milligrams as phosphorus per litre; DL = detection limit; < = less than.

Figure VII-26 Time Series Plots of Total Phosphorus



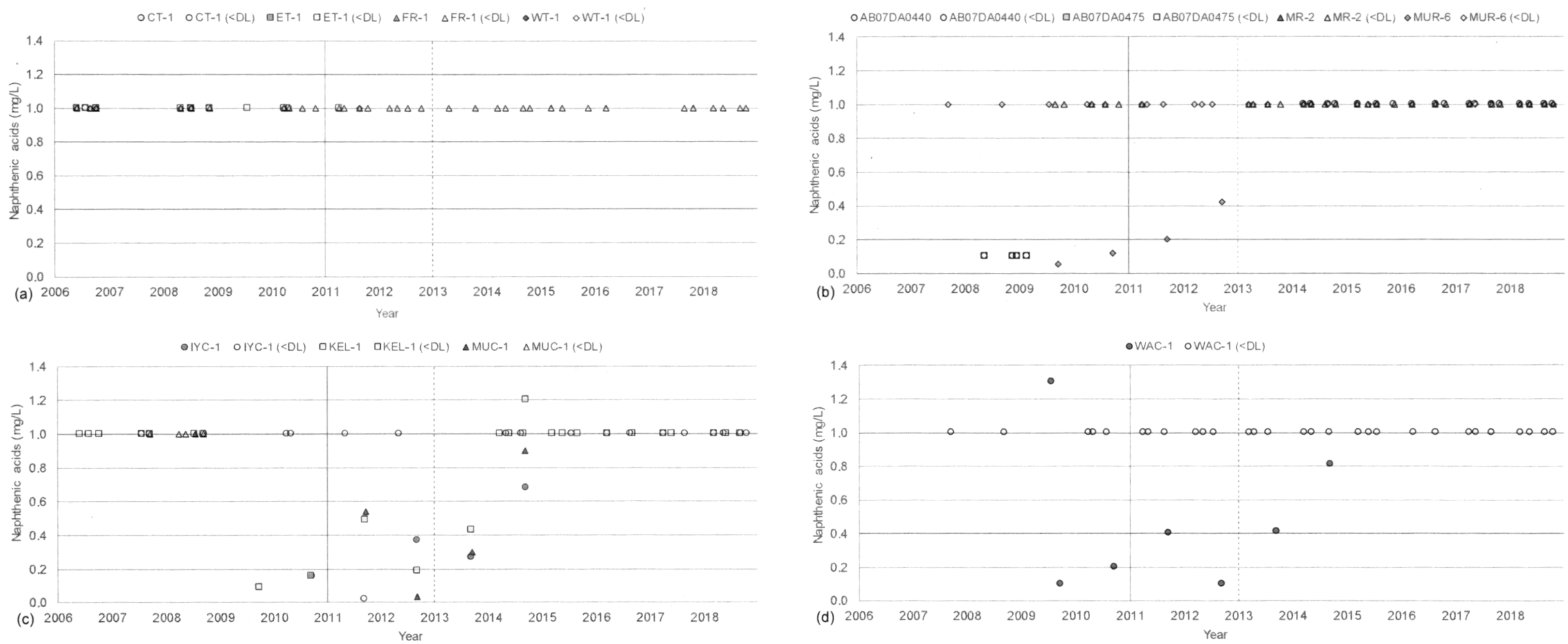
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
mg-P/L = milligrams as phosphorus per litre; DL = detection limit; < = less than.

Figure VII-27 Time Series Plots of Dissolved Phosphorus



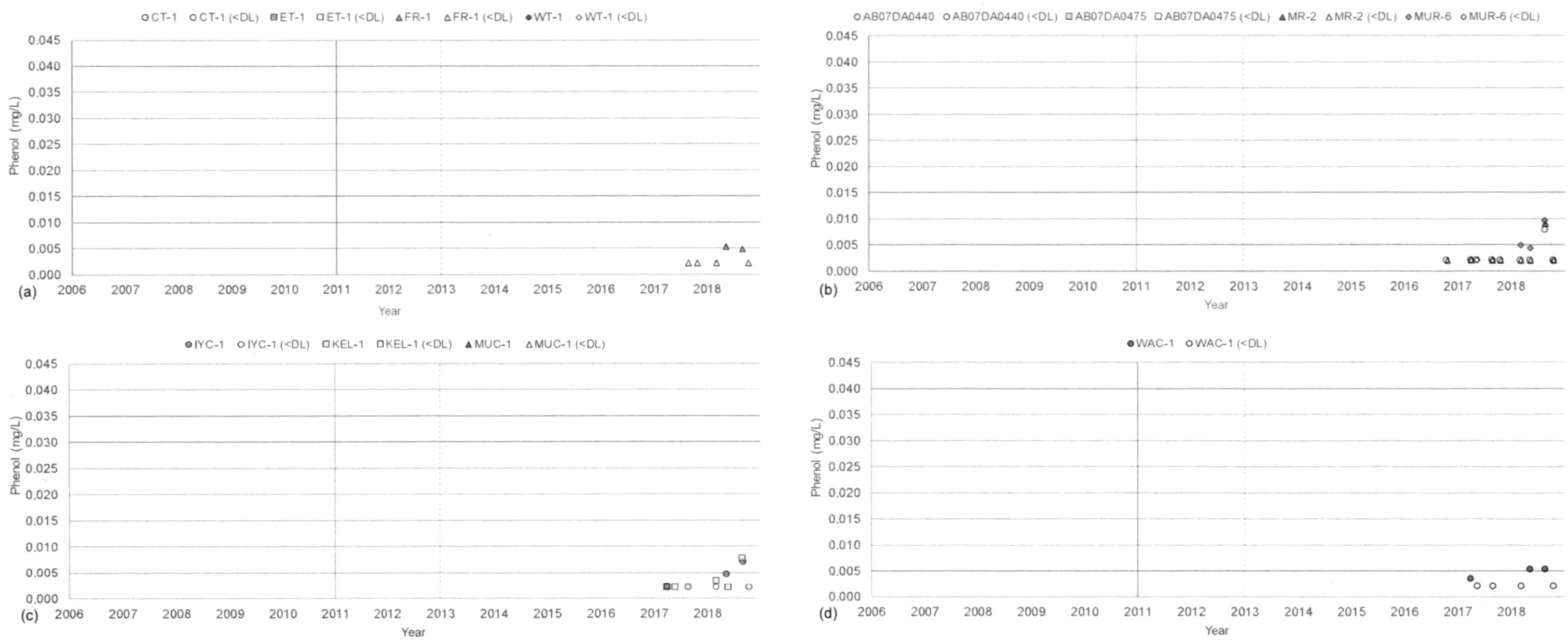
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-28 **Time Series Plots of Biochemical Oxygen Demand**



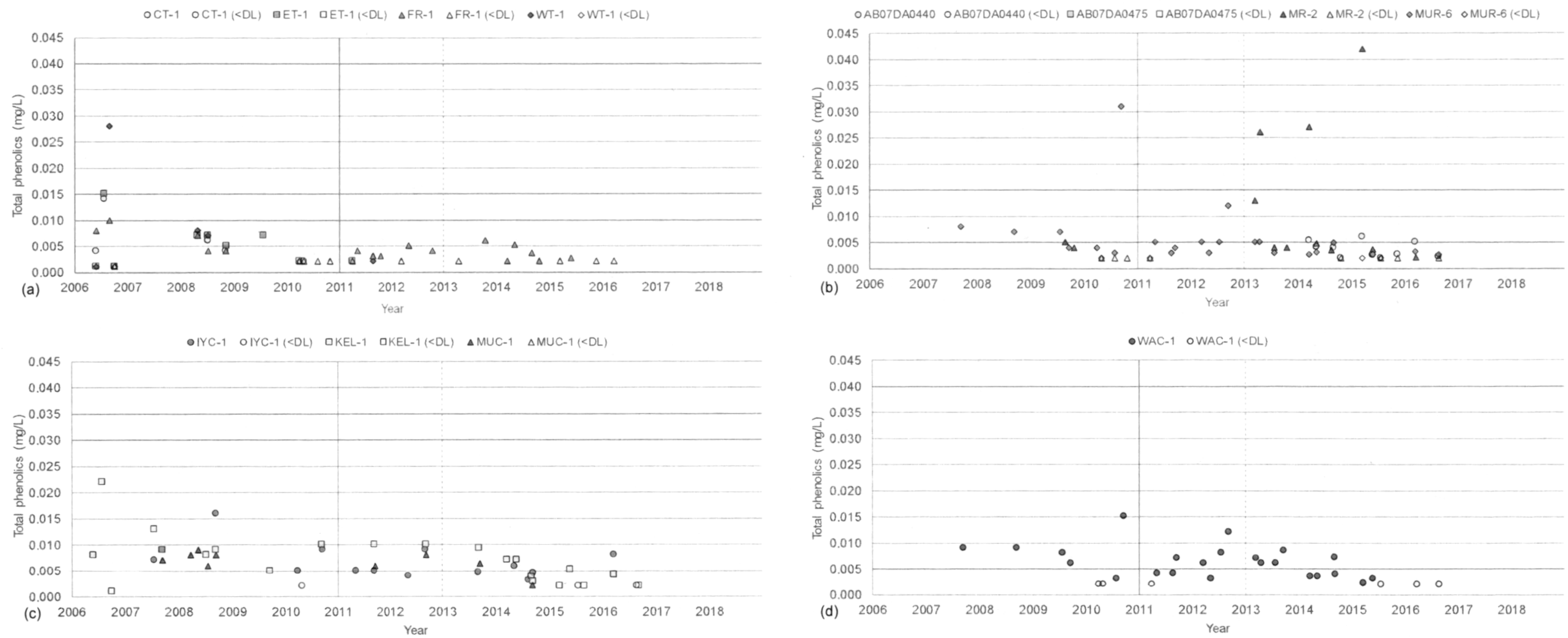
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-29 **Time Series Plots of Naphthenic Acids**



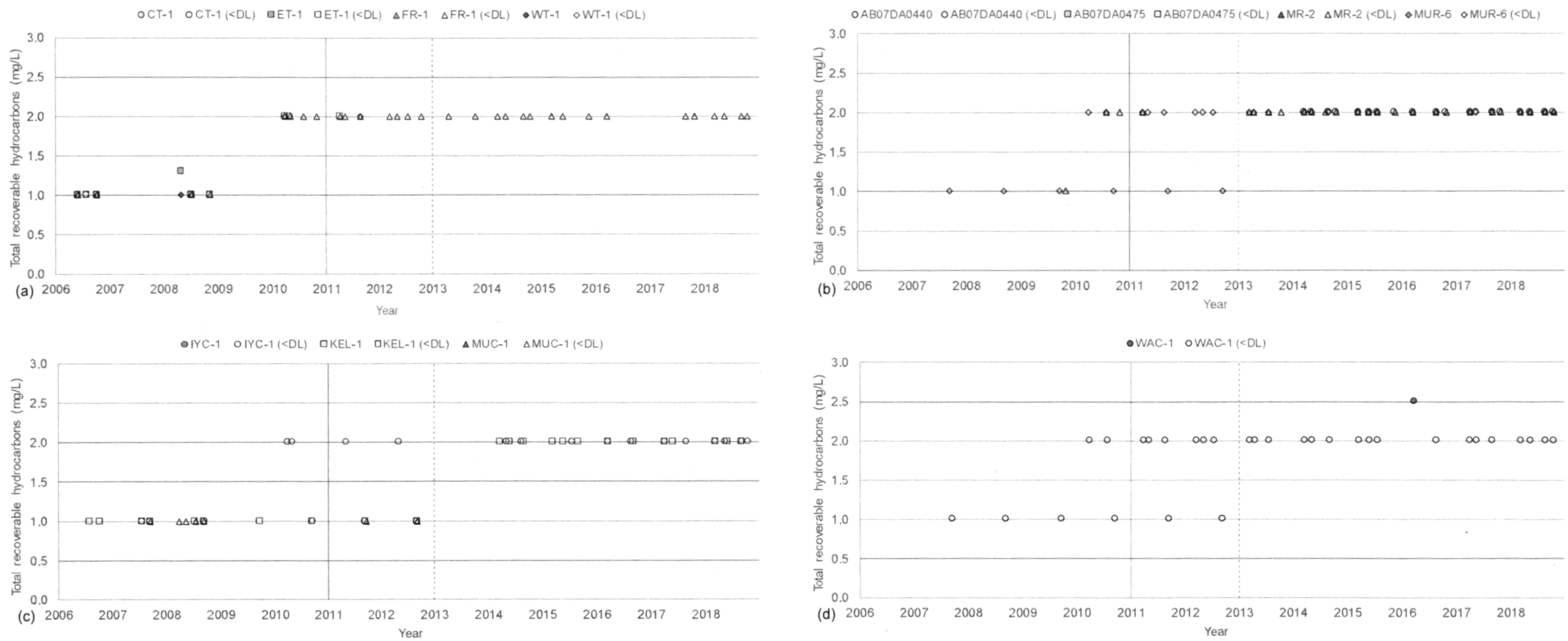
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-30 **Time Series Plots of Phenol**



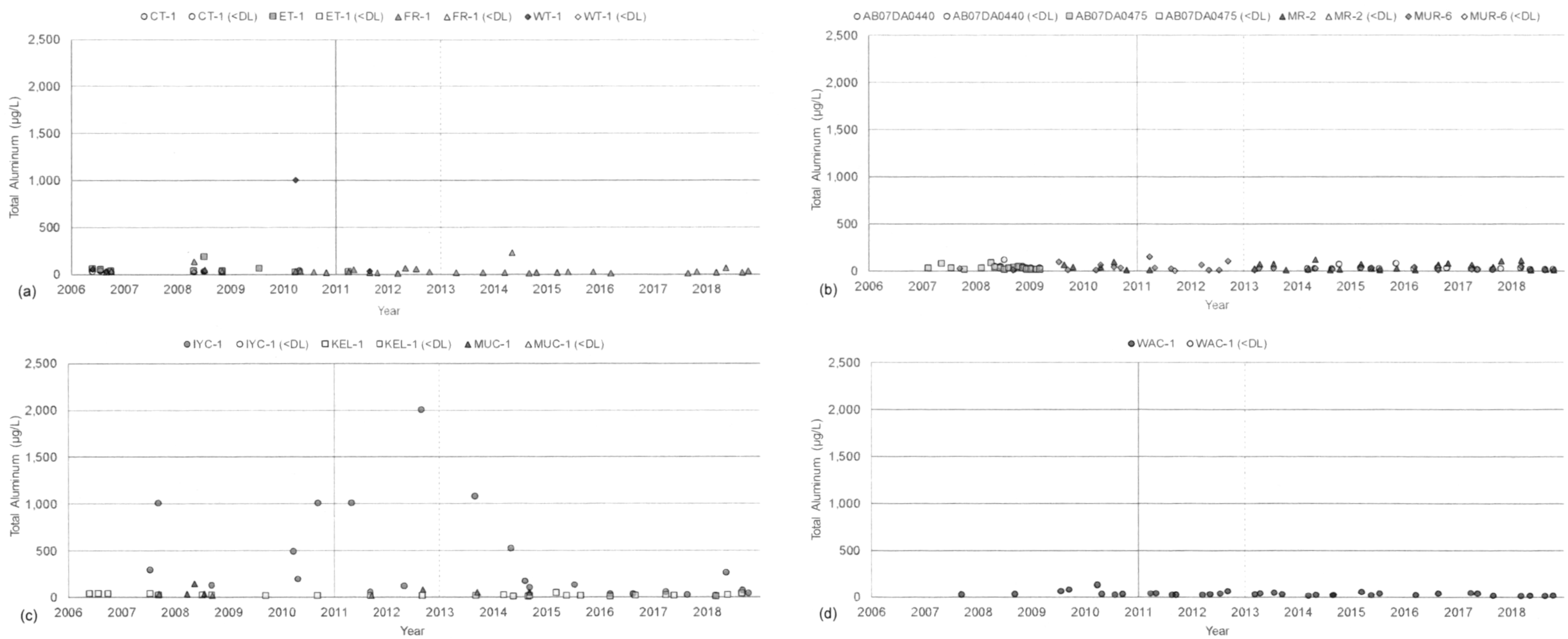
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-31 **Time Series Plots of Total Phenolics**



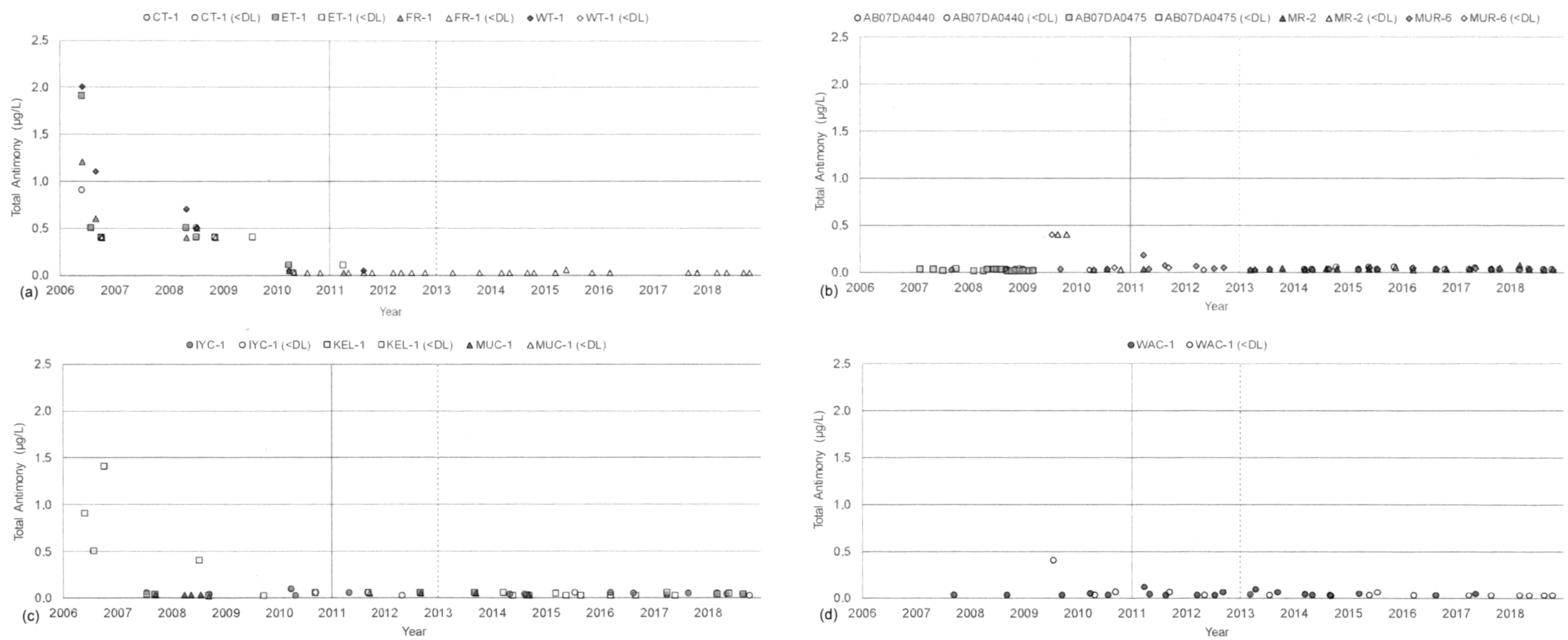
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-32 Time Series Plots of Total Recoverable Hydrocarbons



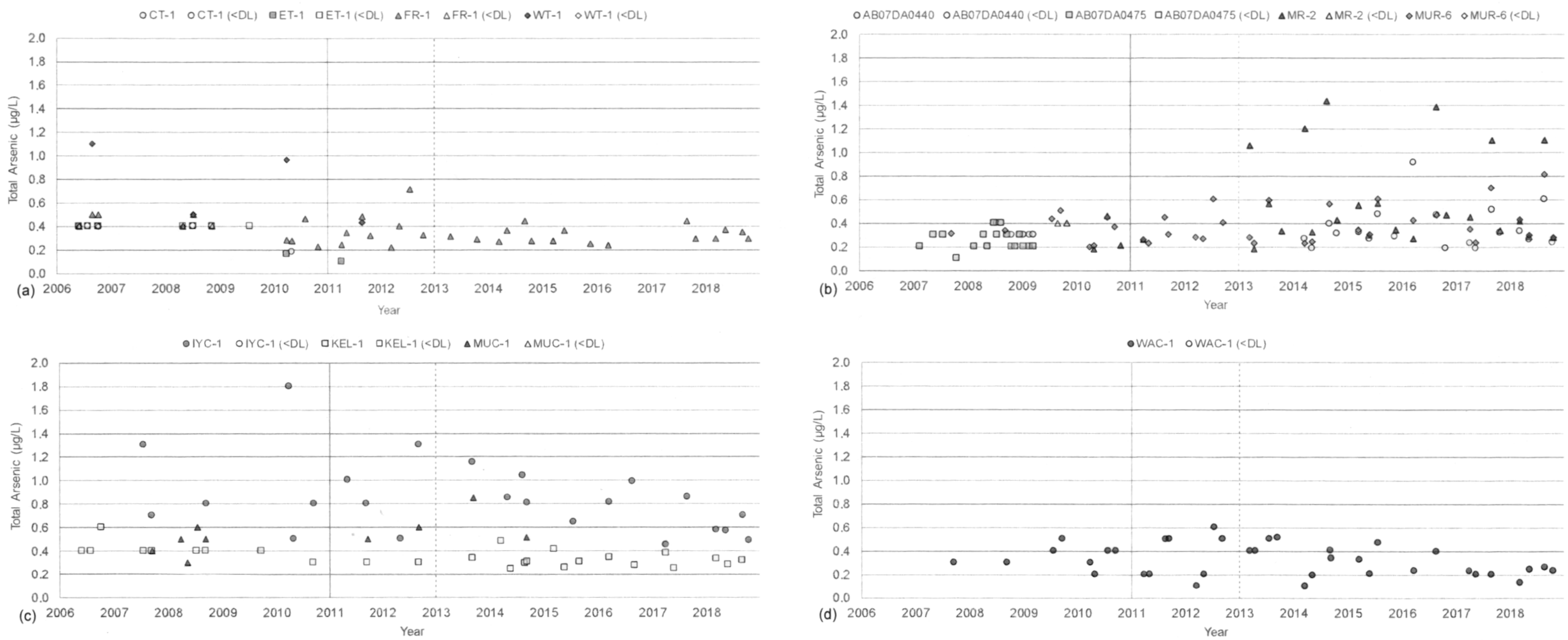
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-33 Time Series Plots of Total Aluminum



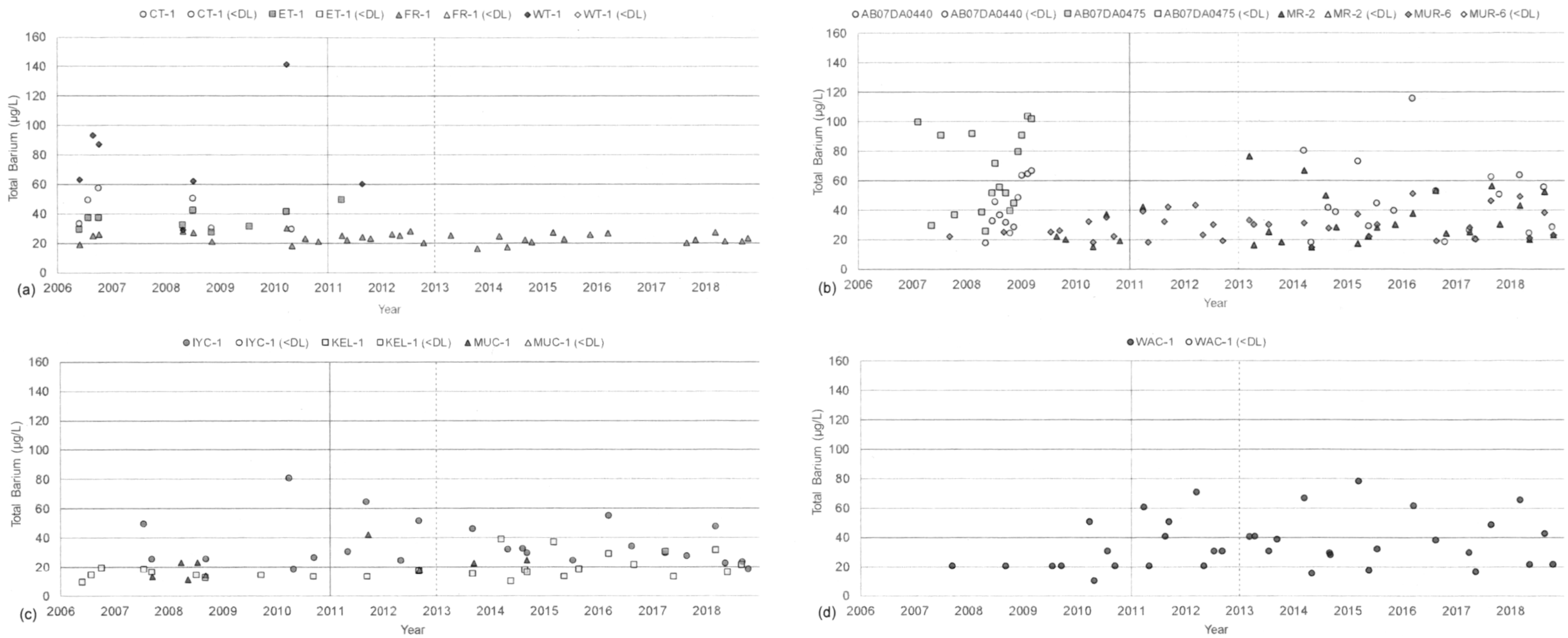
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-34 Time Series Plots of Total Antimony



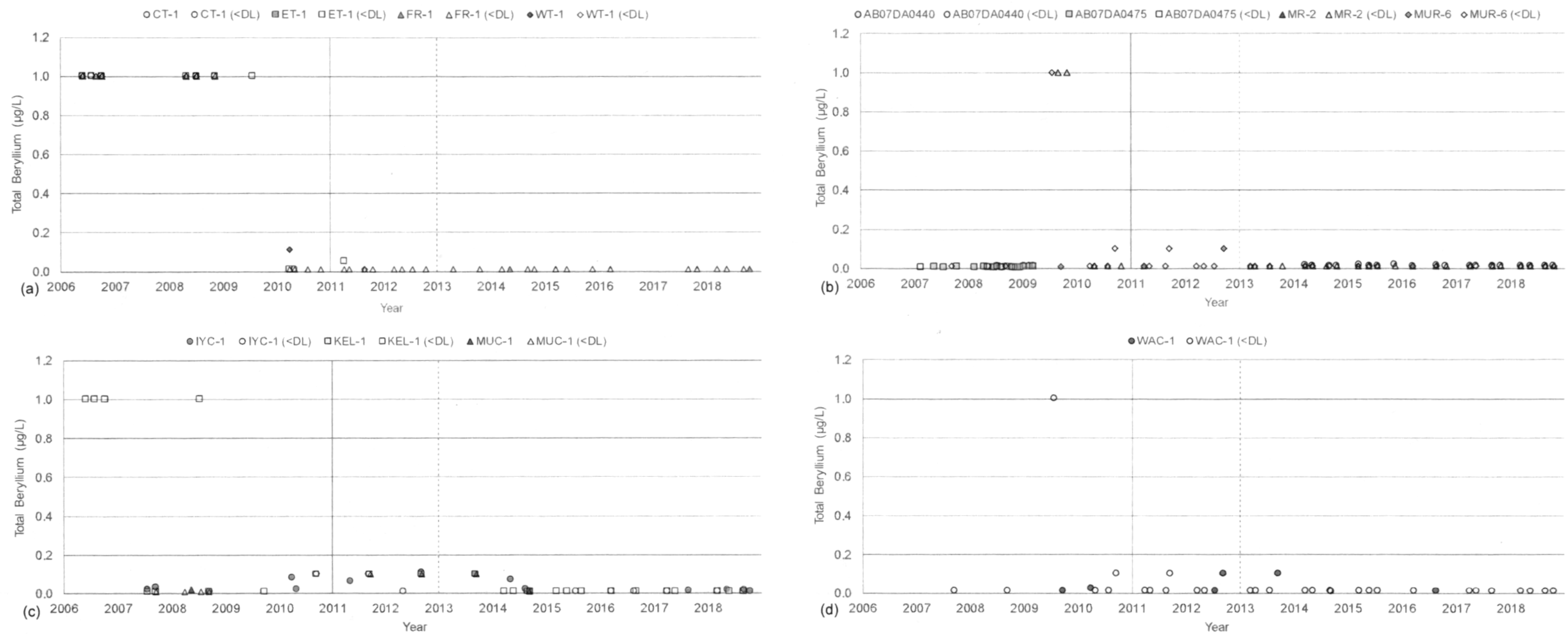
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-35 **Time Series Plots of Total Arsenic**



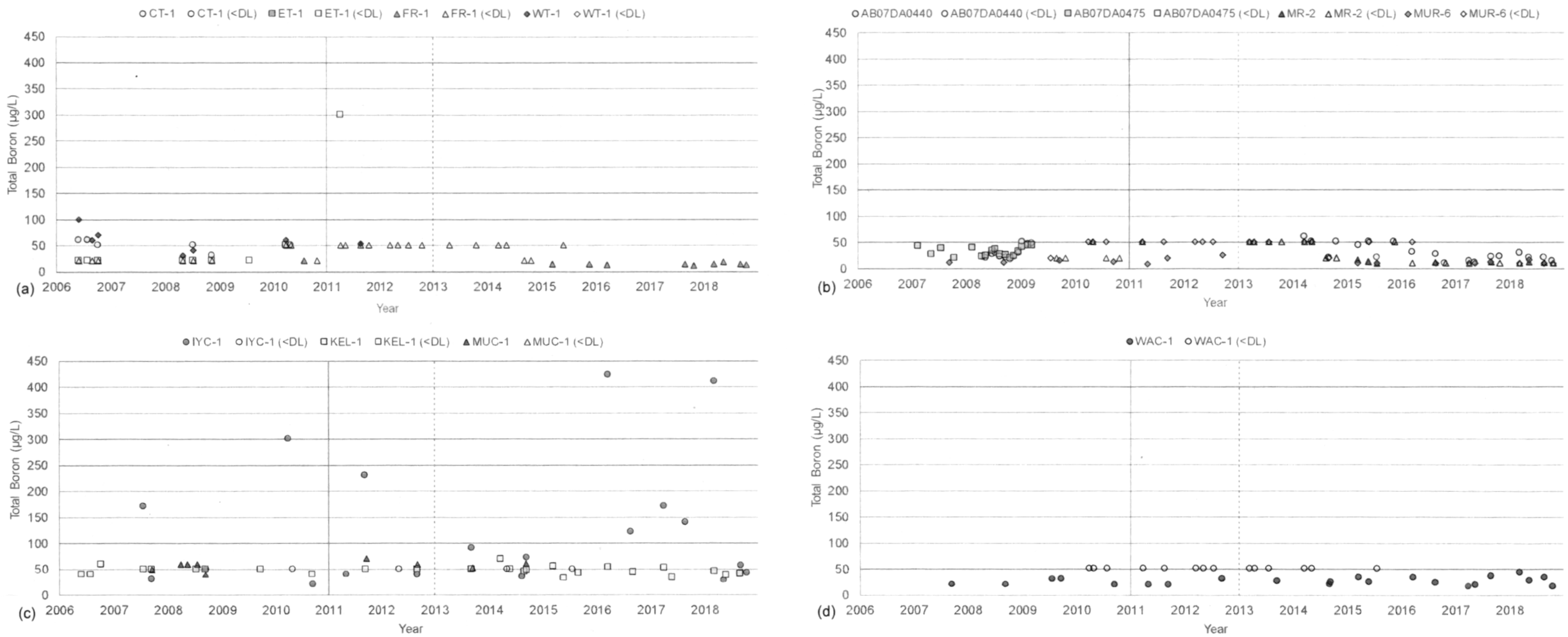
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-36 **Time Series Plots of Total Barium**



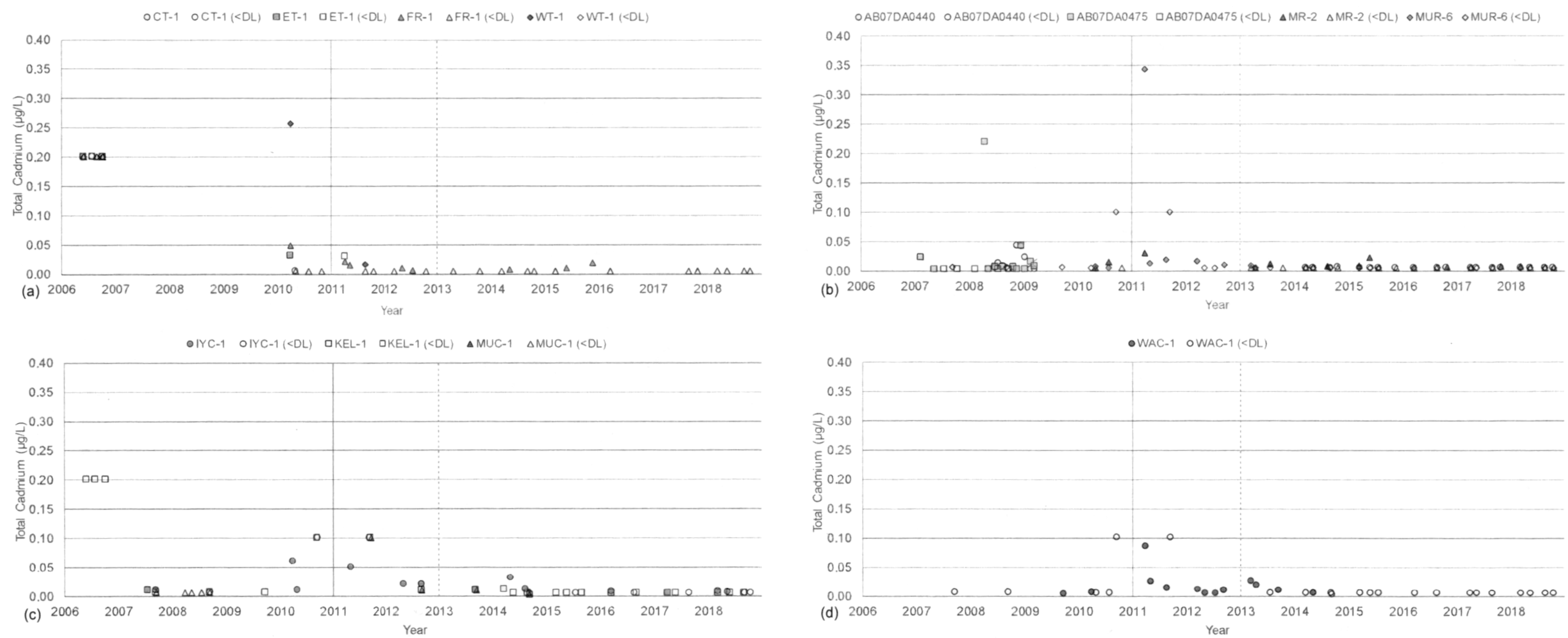
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-37 Time Series Plots of Total Beryllium



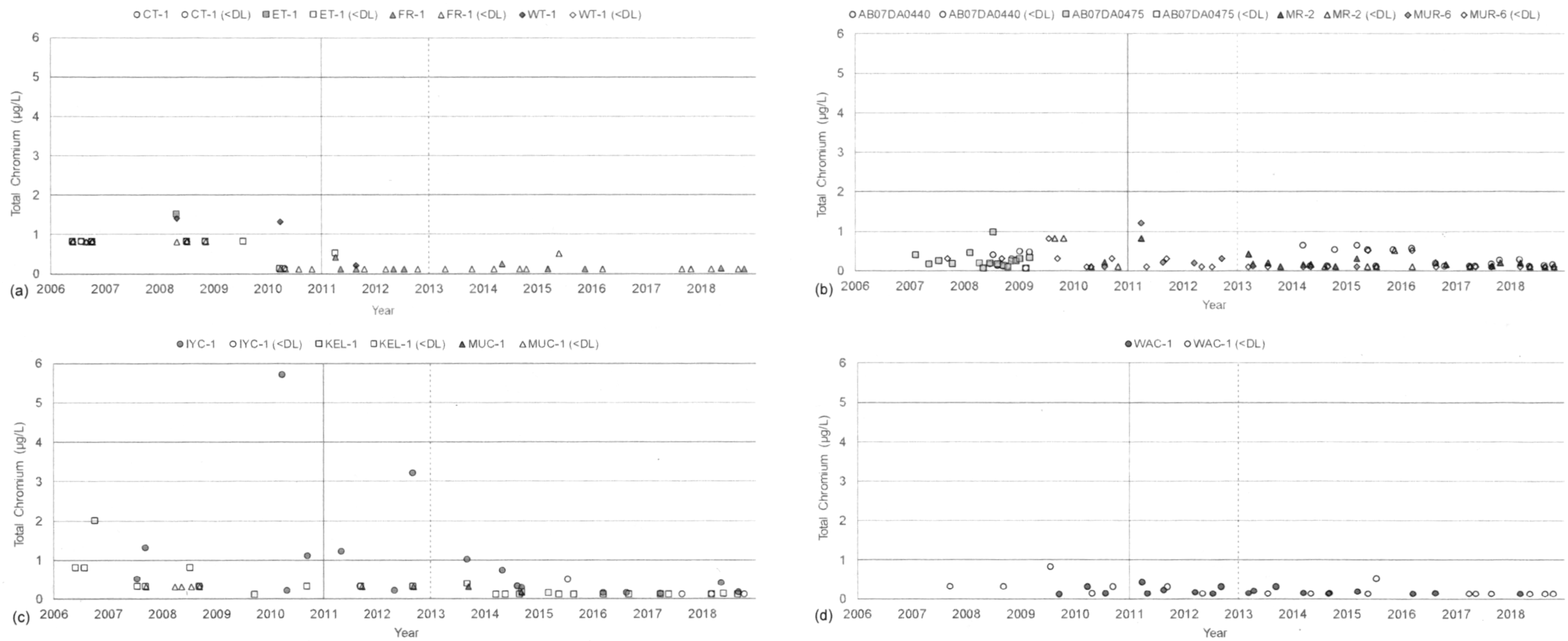
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-38 **Time Series Plots of Total Boron**



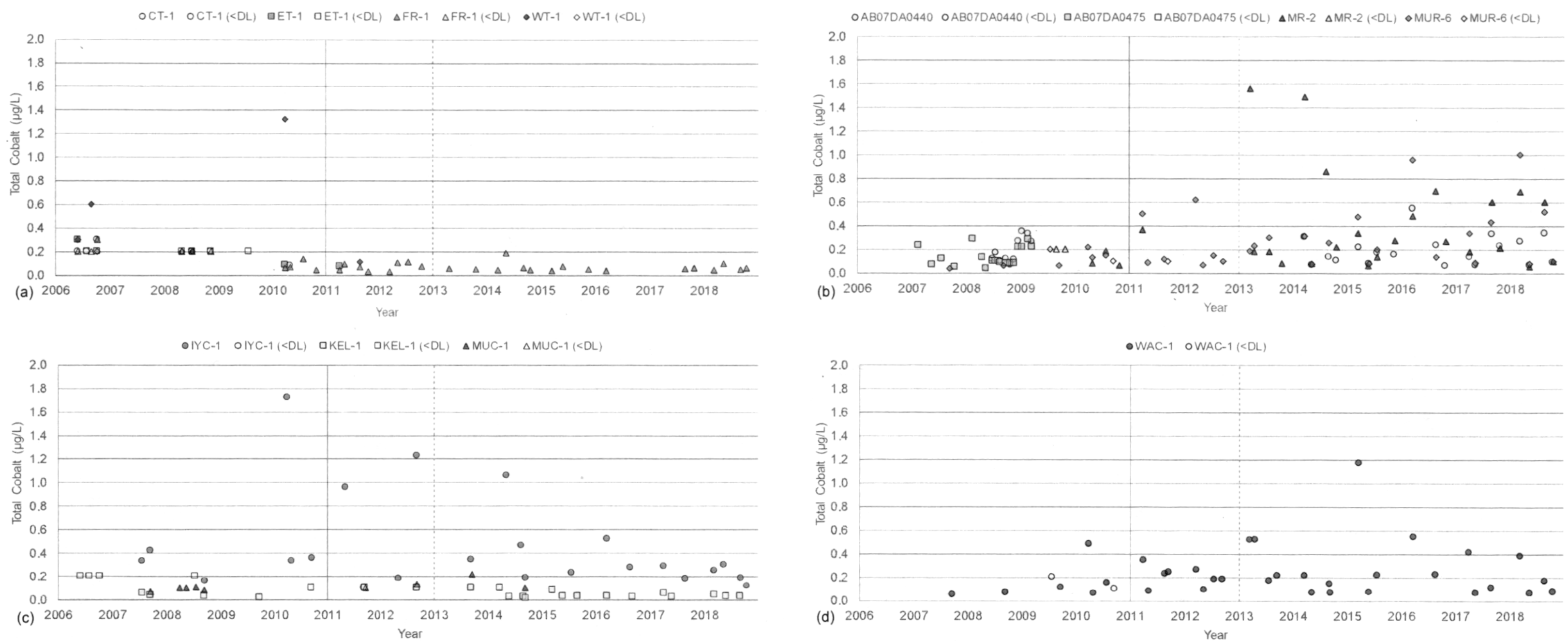
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-39 **Time Series Plots of Total Cadmium**



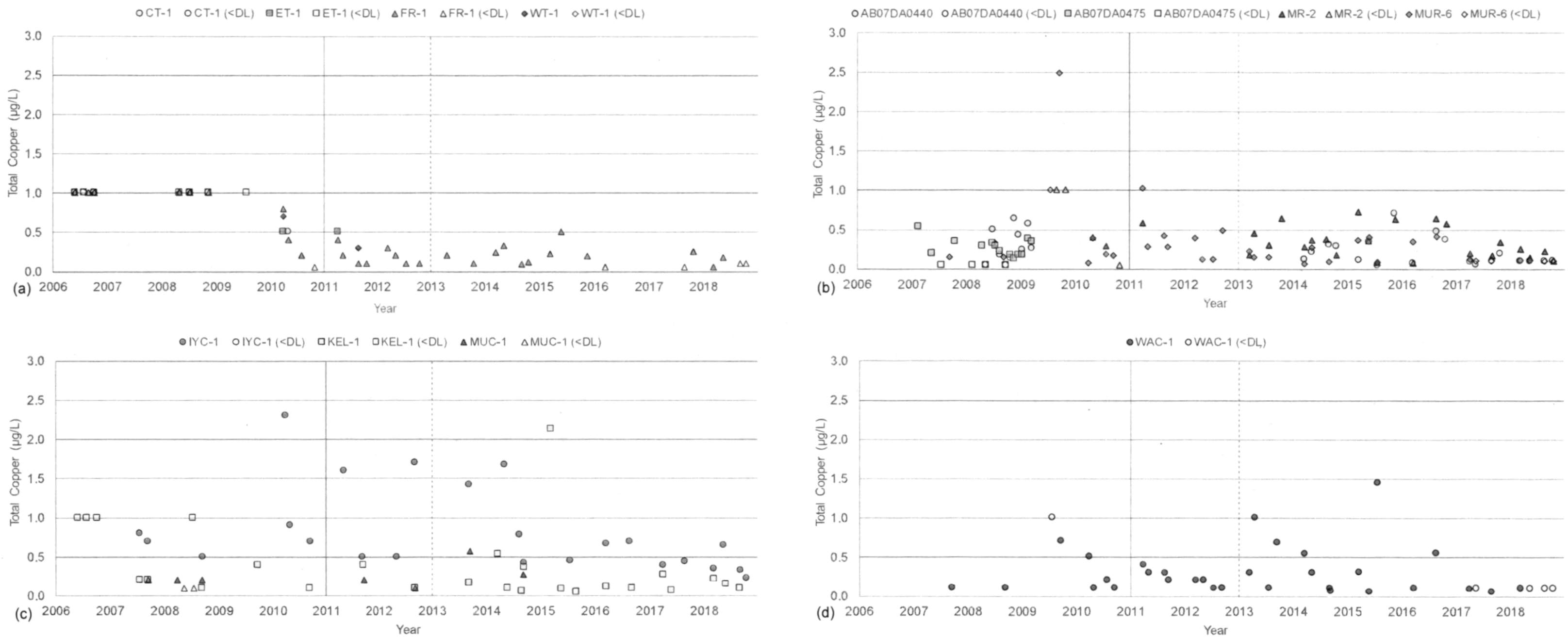
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-40 **Time Series Plots of Total Chromium**



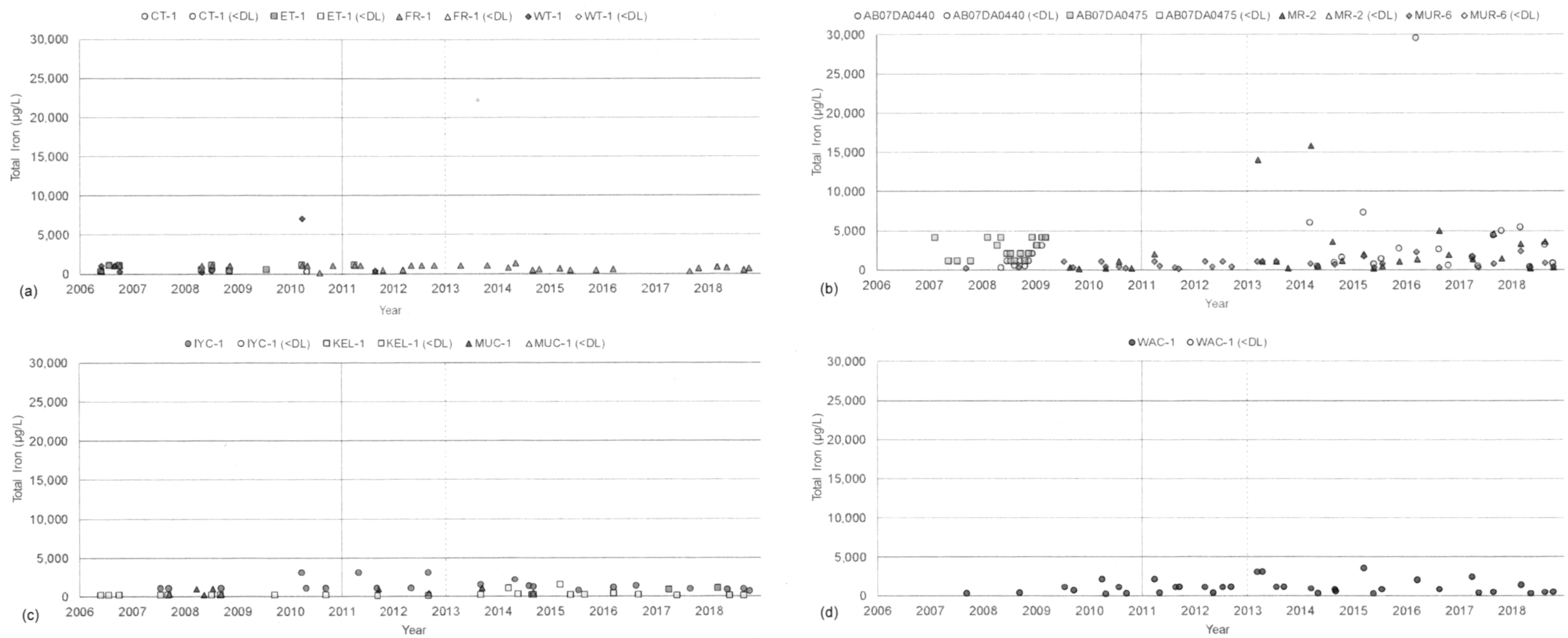
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-41 Time Series Plots of Total Cobalt



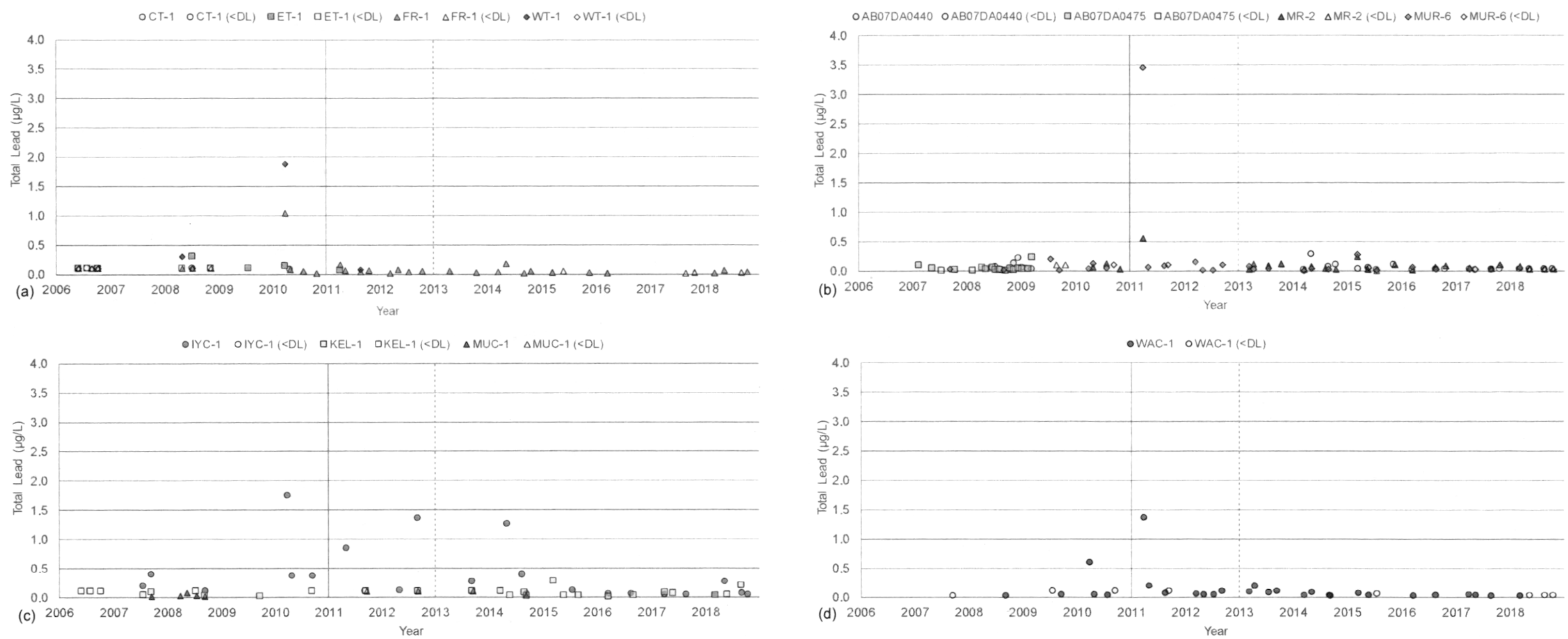
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-42 **Time Series Plots of Total Copper**



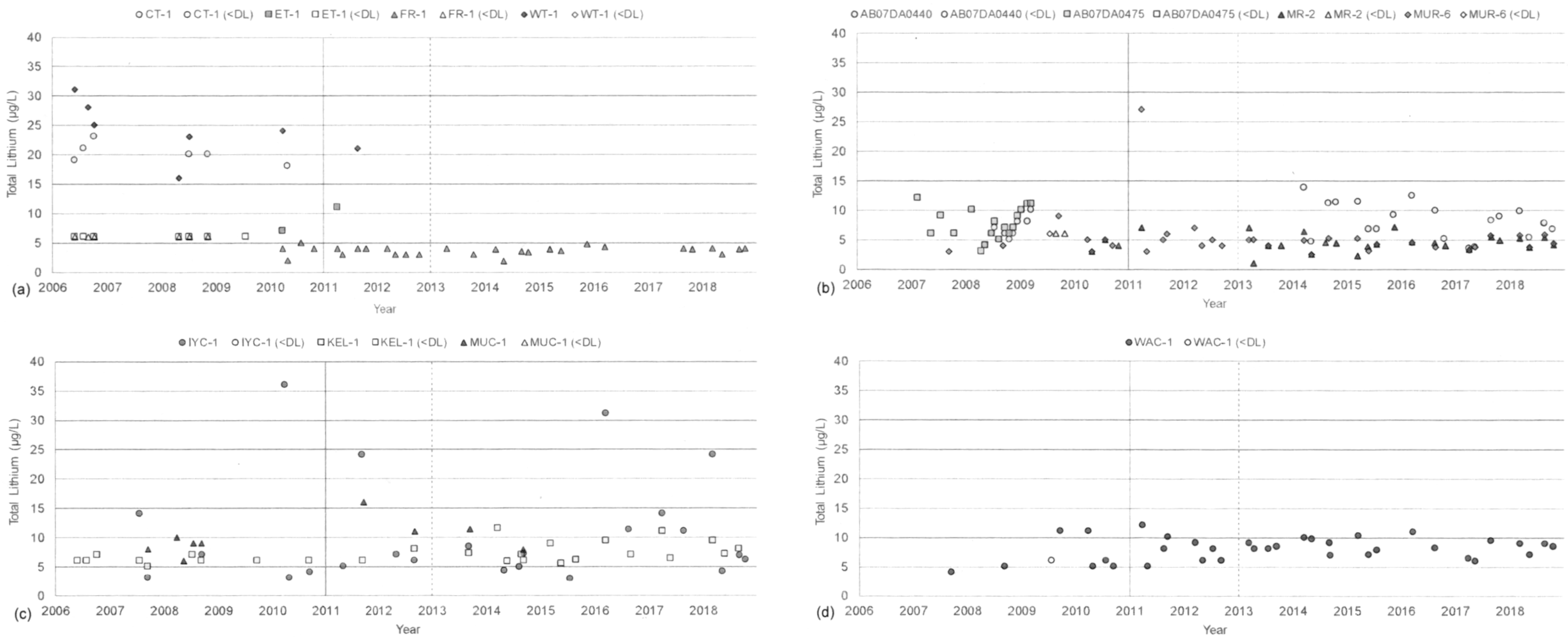
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-43 **Time Series Plots of Total Iron**



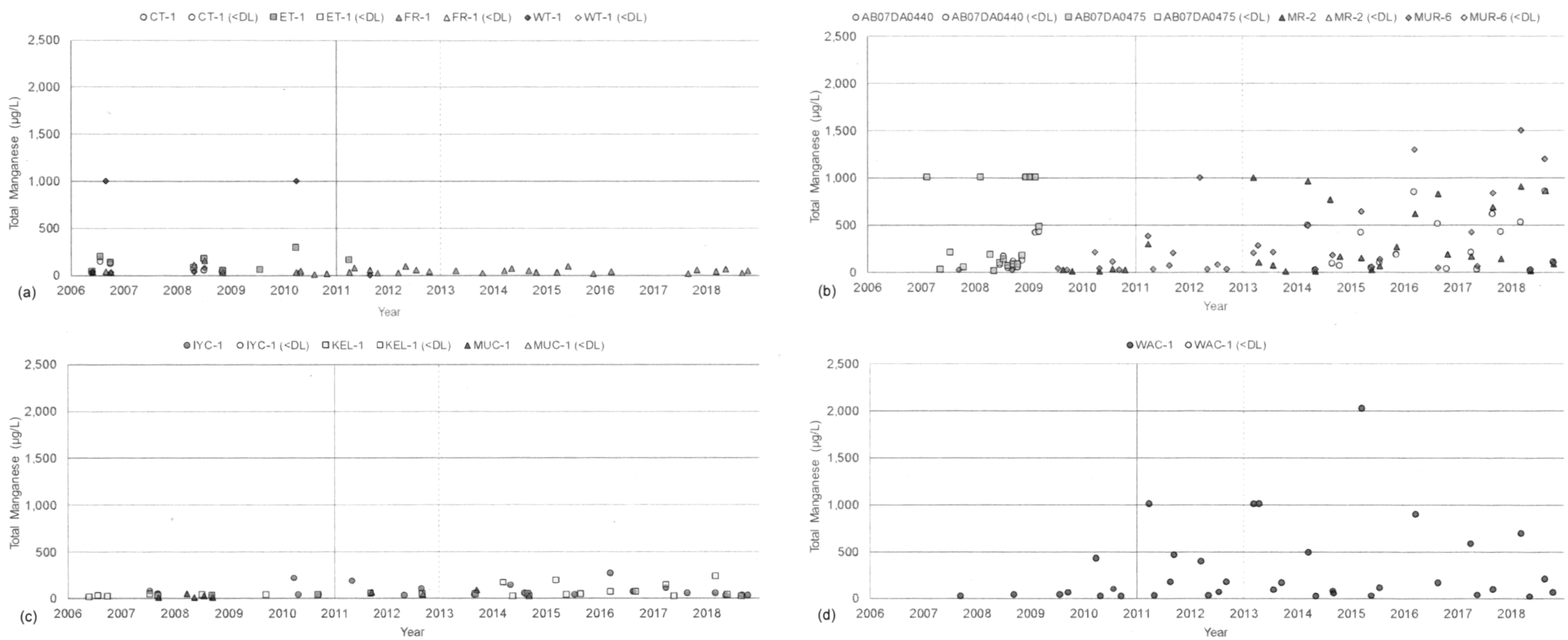
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-44 **Time Series Plots of Total Lead**



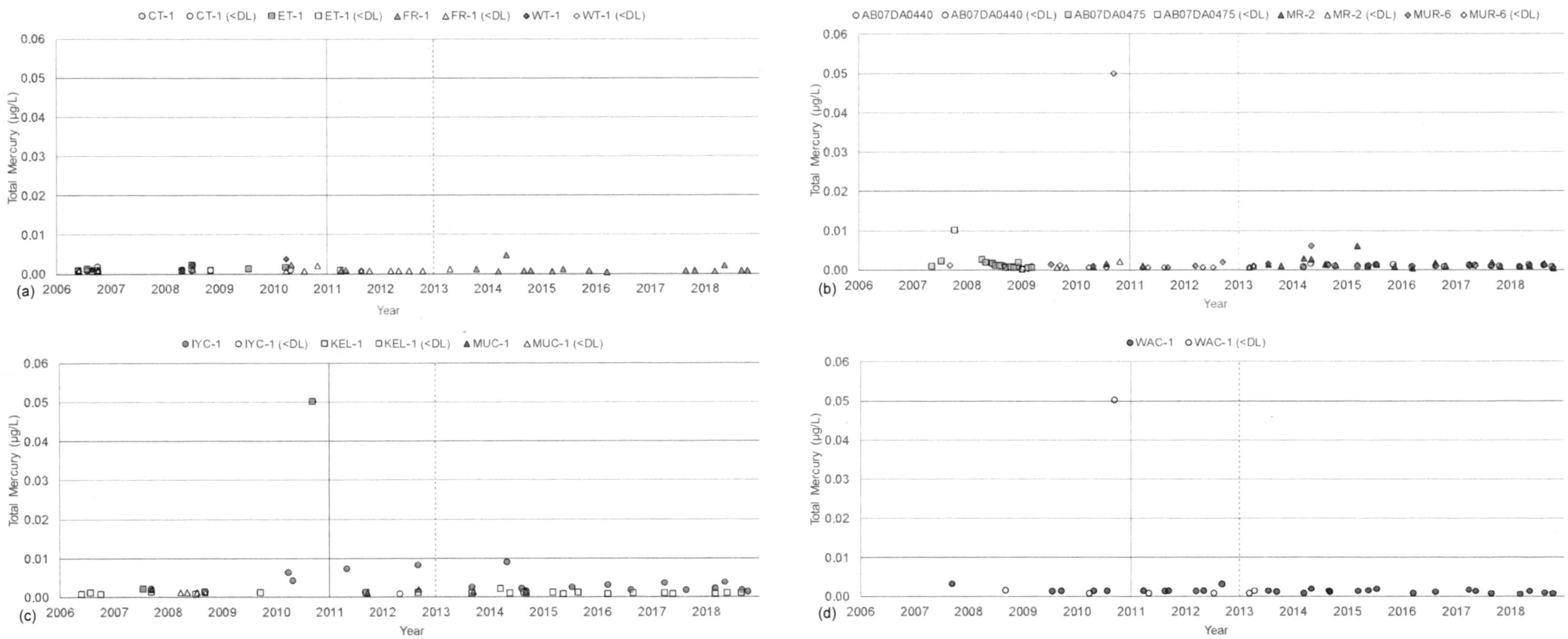
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-45 **Time Series Plots of Total Lithium**



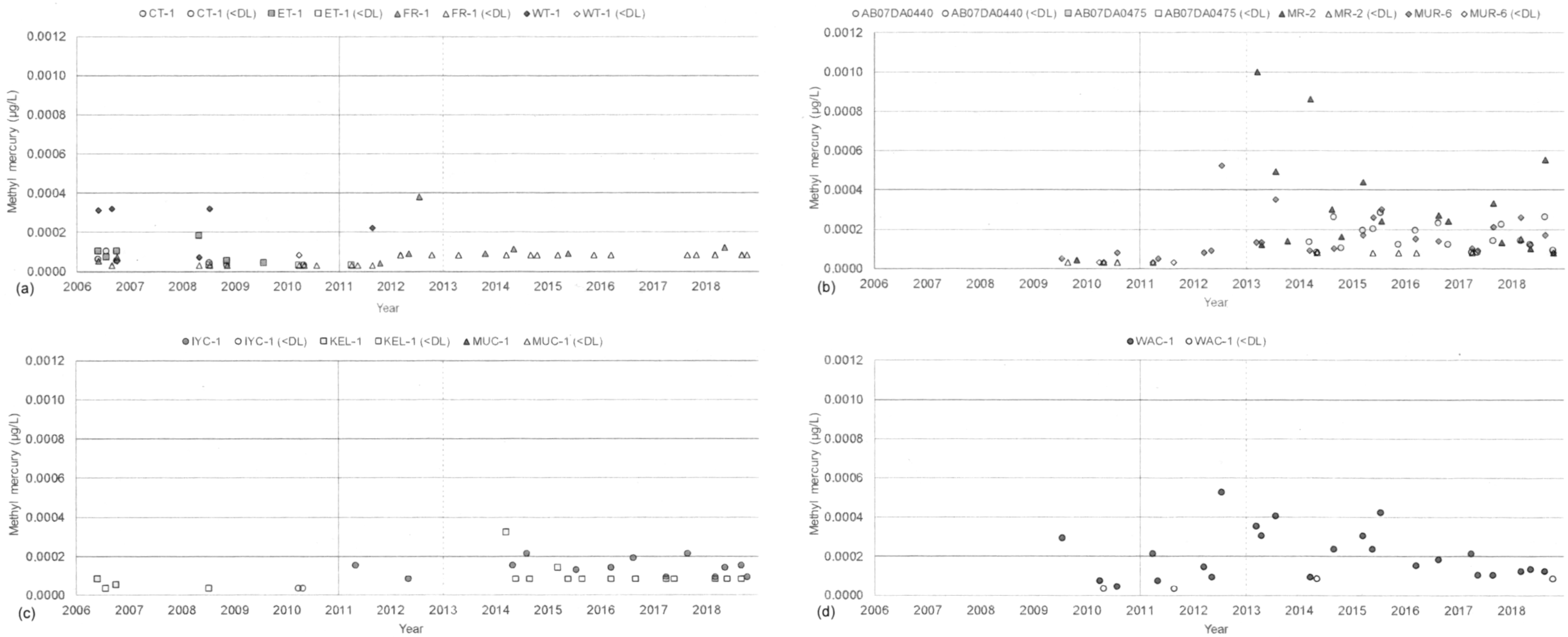
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-46 **Time Series Plots of Total Manganese**



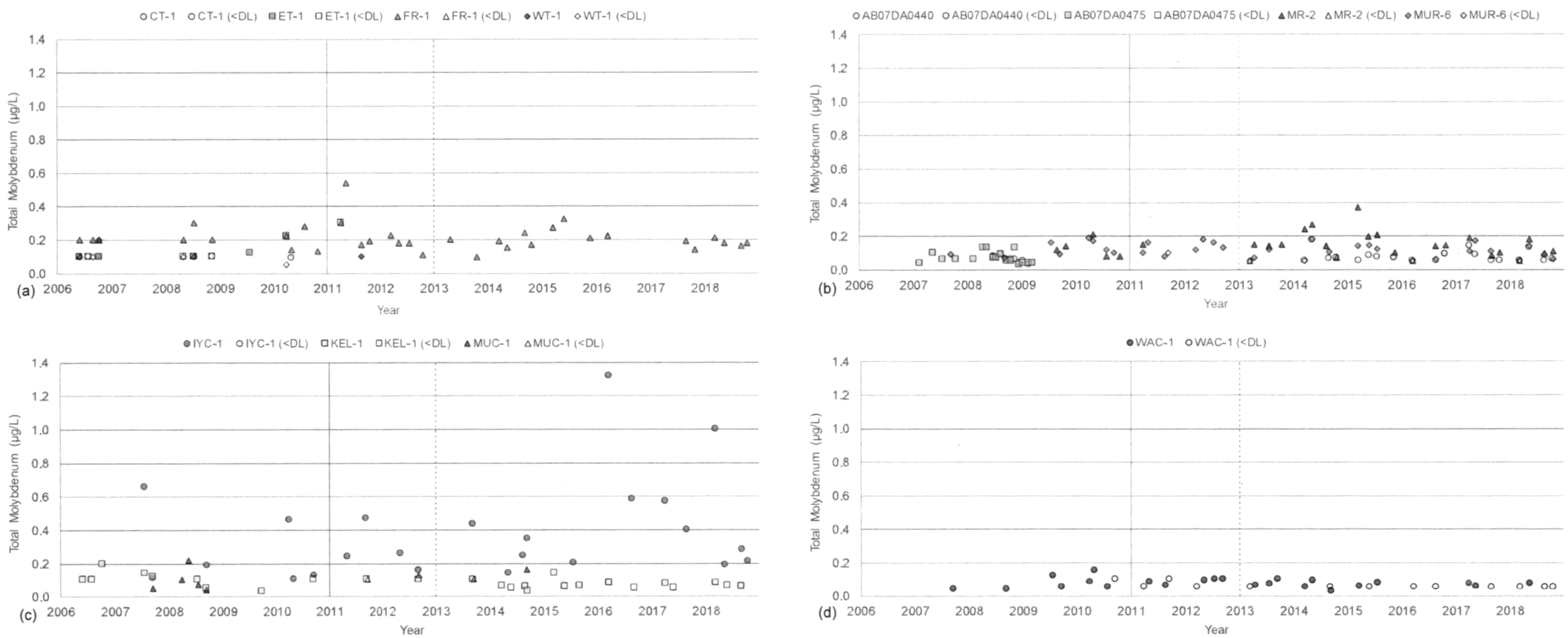
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-47 **Time Series Plots of Total Mercury**



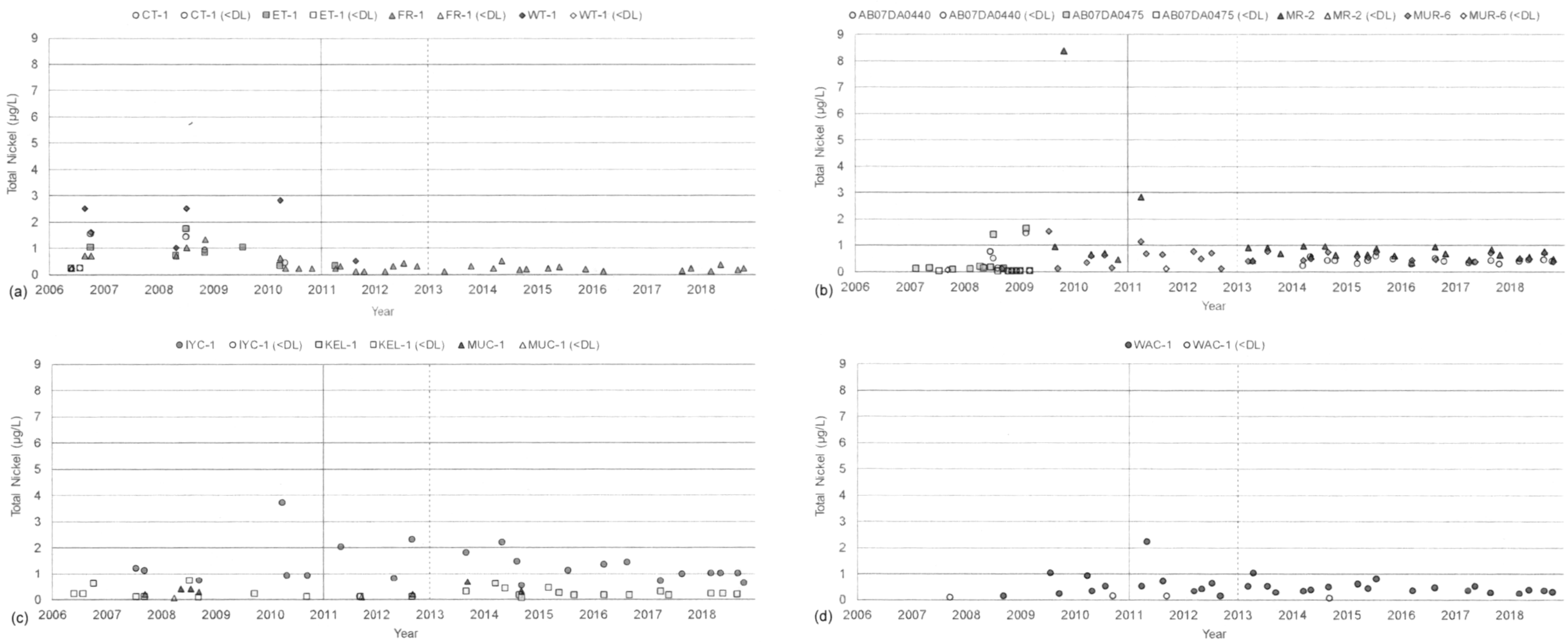
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-48 **Time Series Plots of Methyl Mercury**



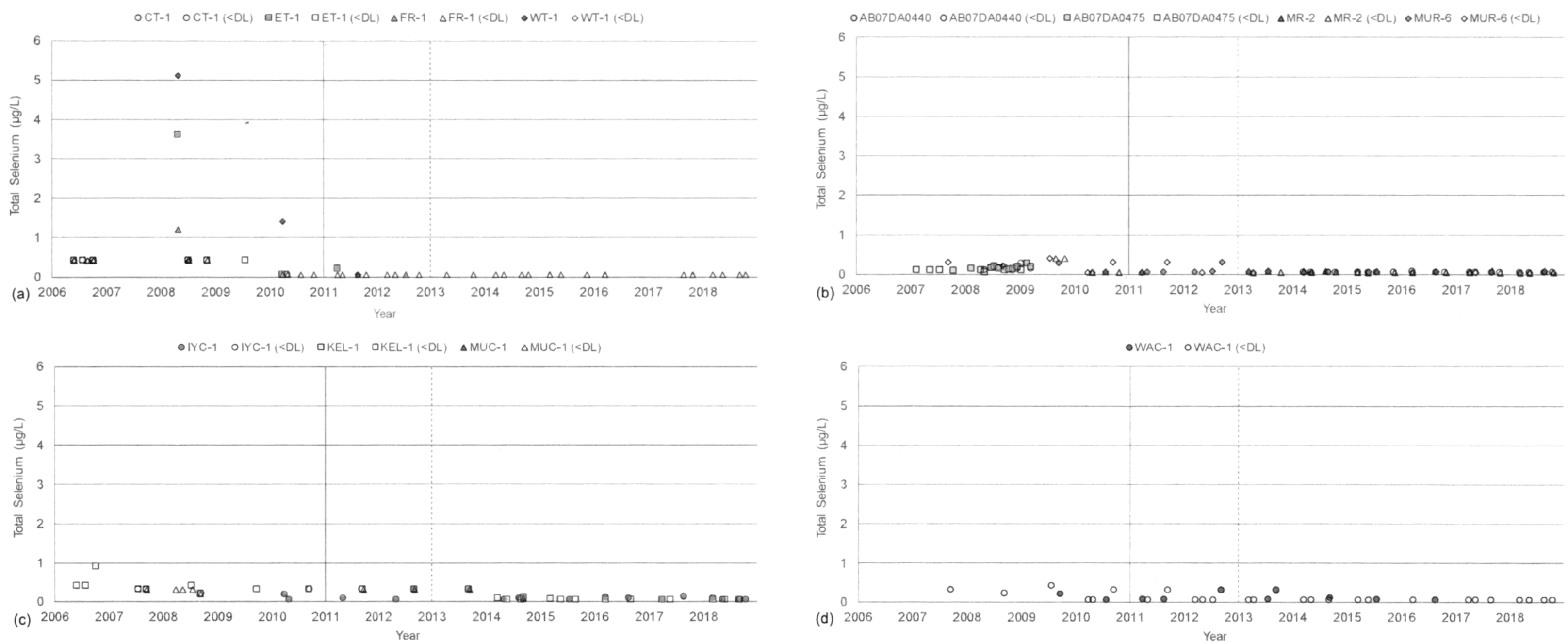
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-49 **Time Series Plots of Total Molybdenum**



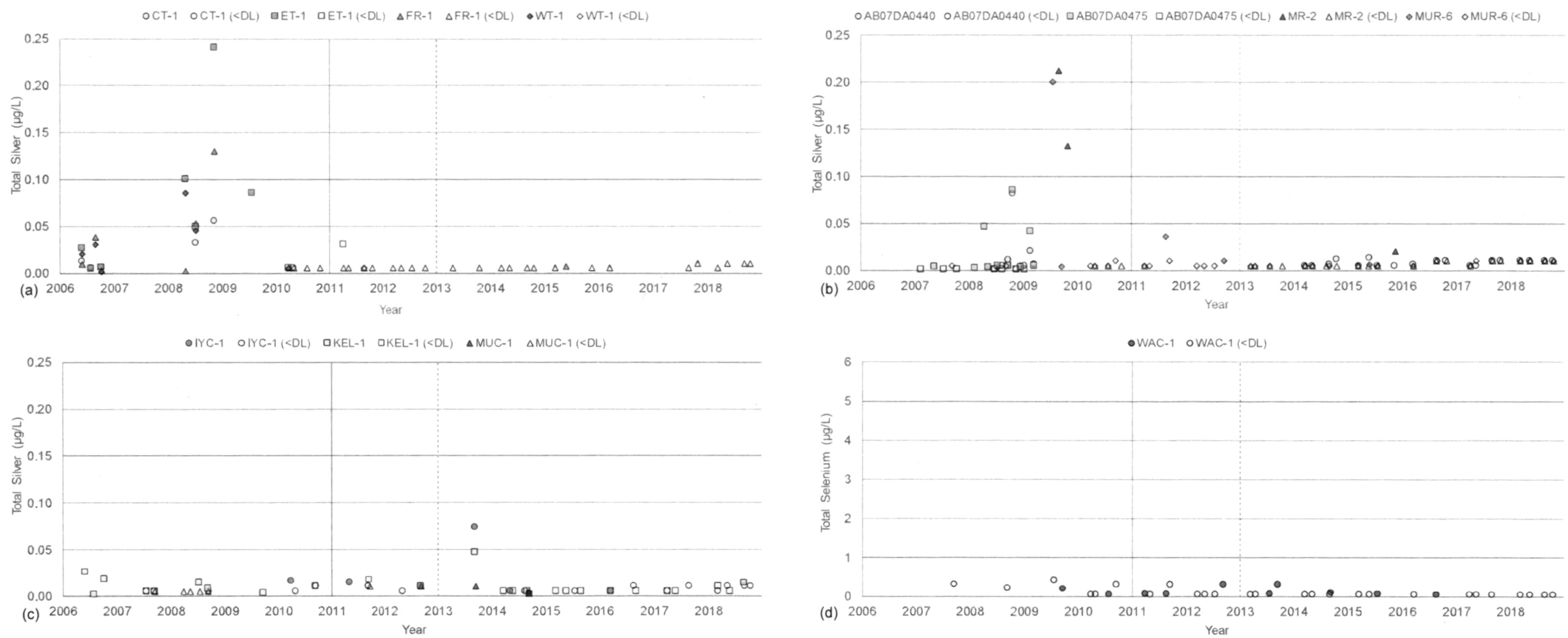
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-50 Time Series Plots of Total Nickel



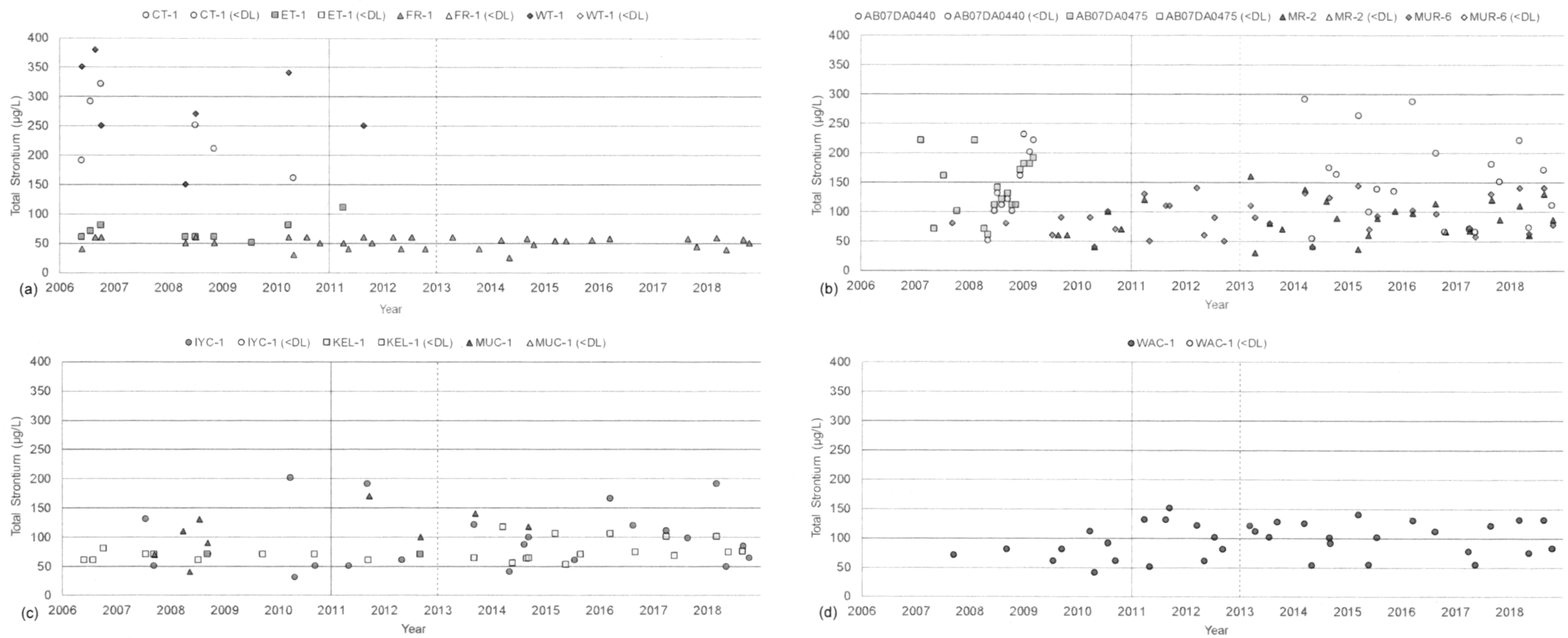
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-51 **Time Series Plots of Total Selenium**



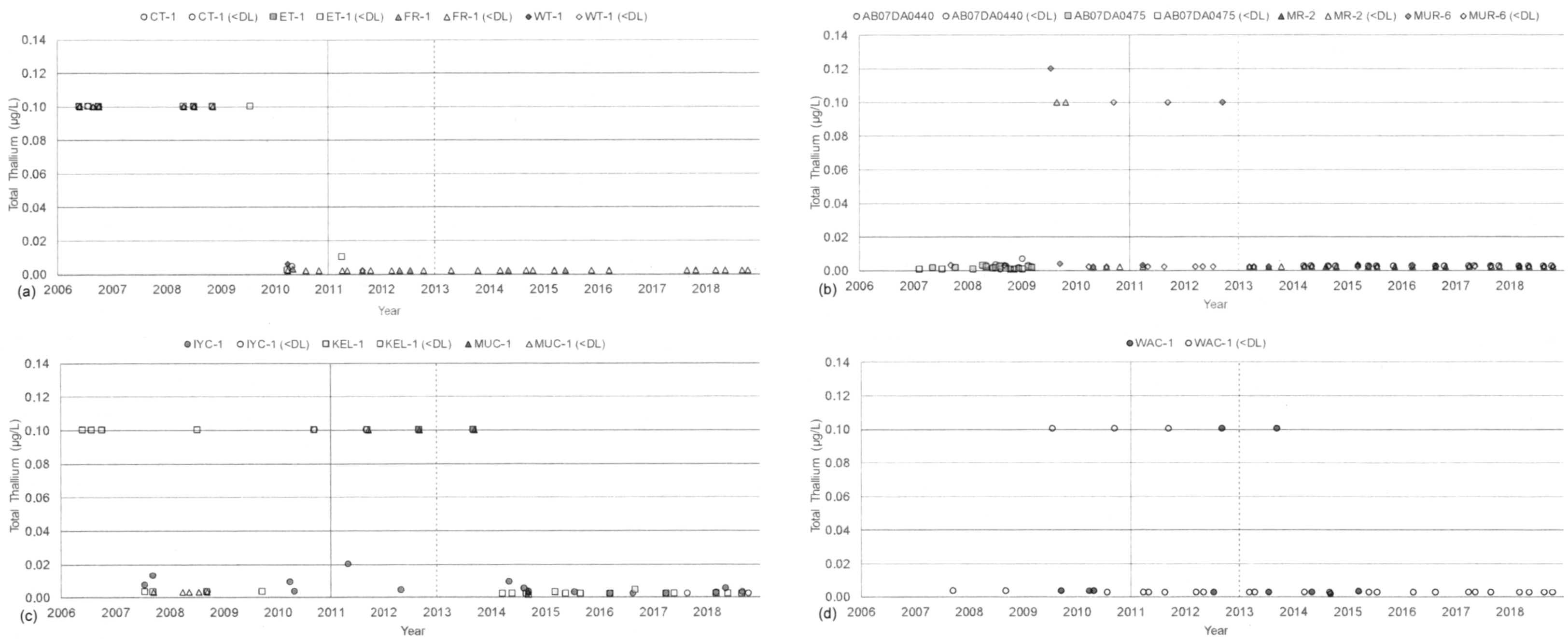
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-52 **Time Series Plots of Total Silver**



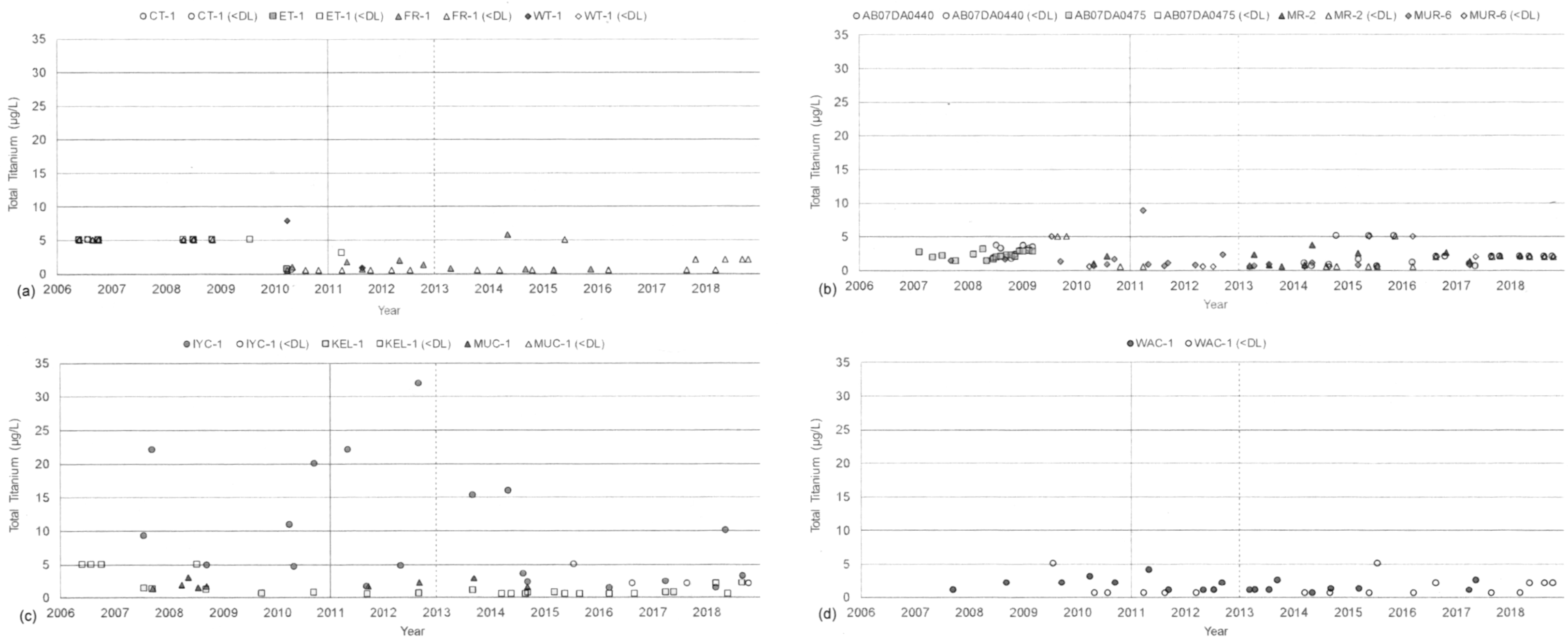
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-53 Time Series Plots of Total Strontium



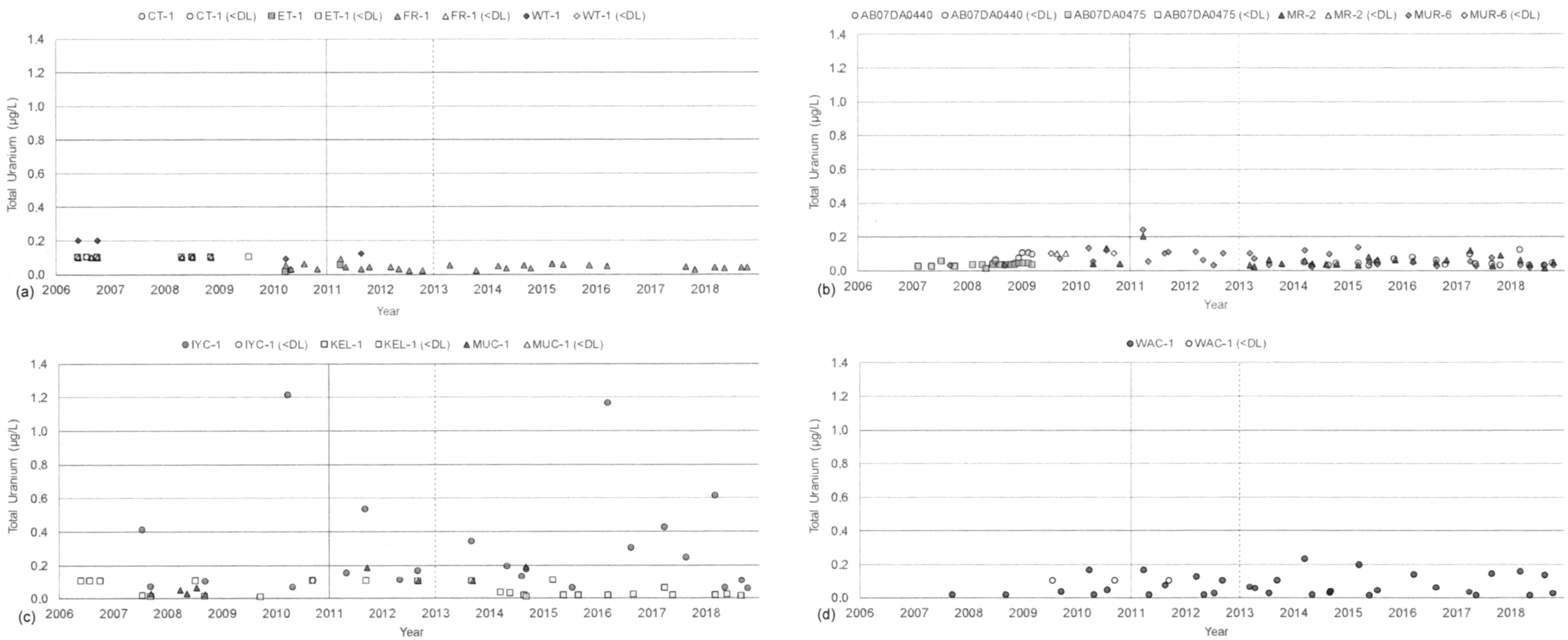
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-54 **Time Series Plots of Total Thallium**



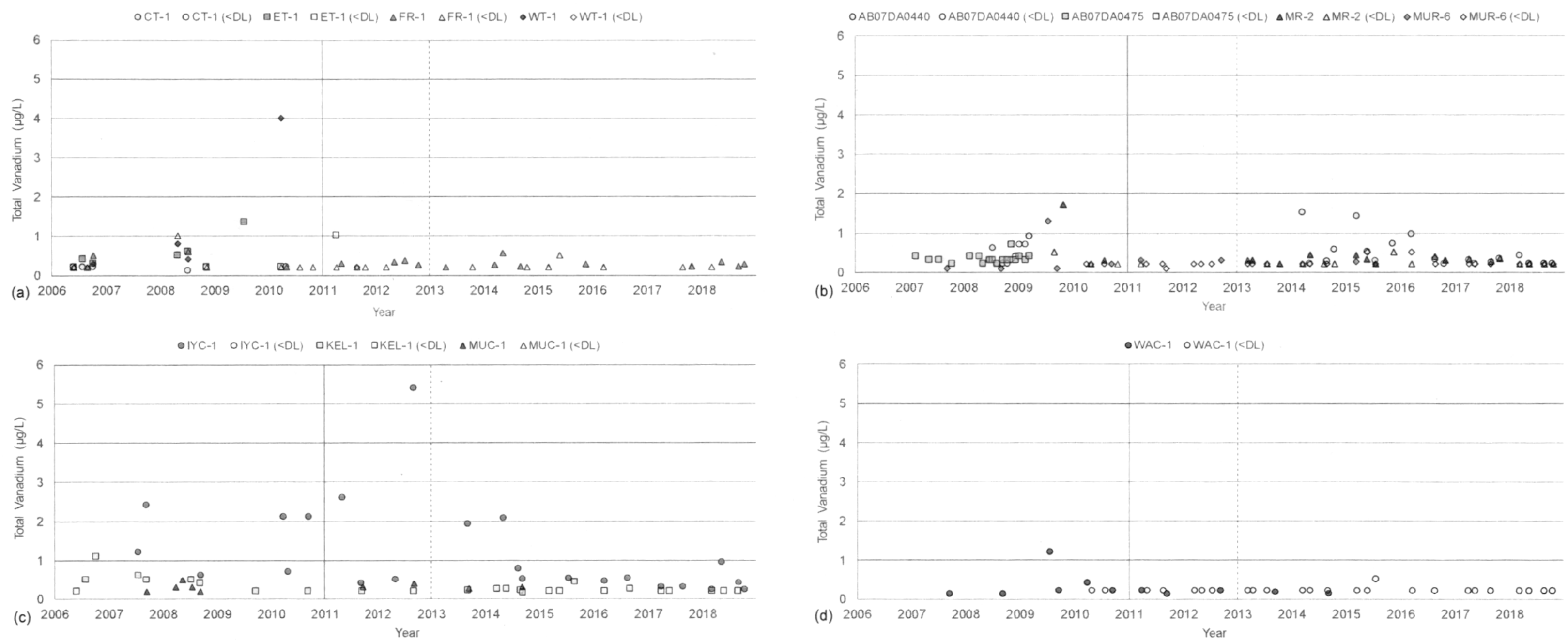
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-55 Time Series Plots of Total Titanium



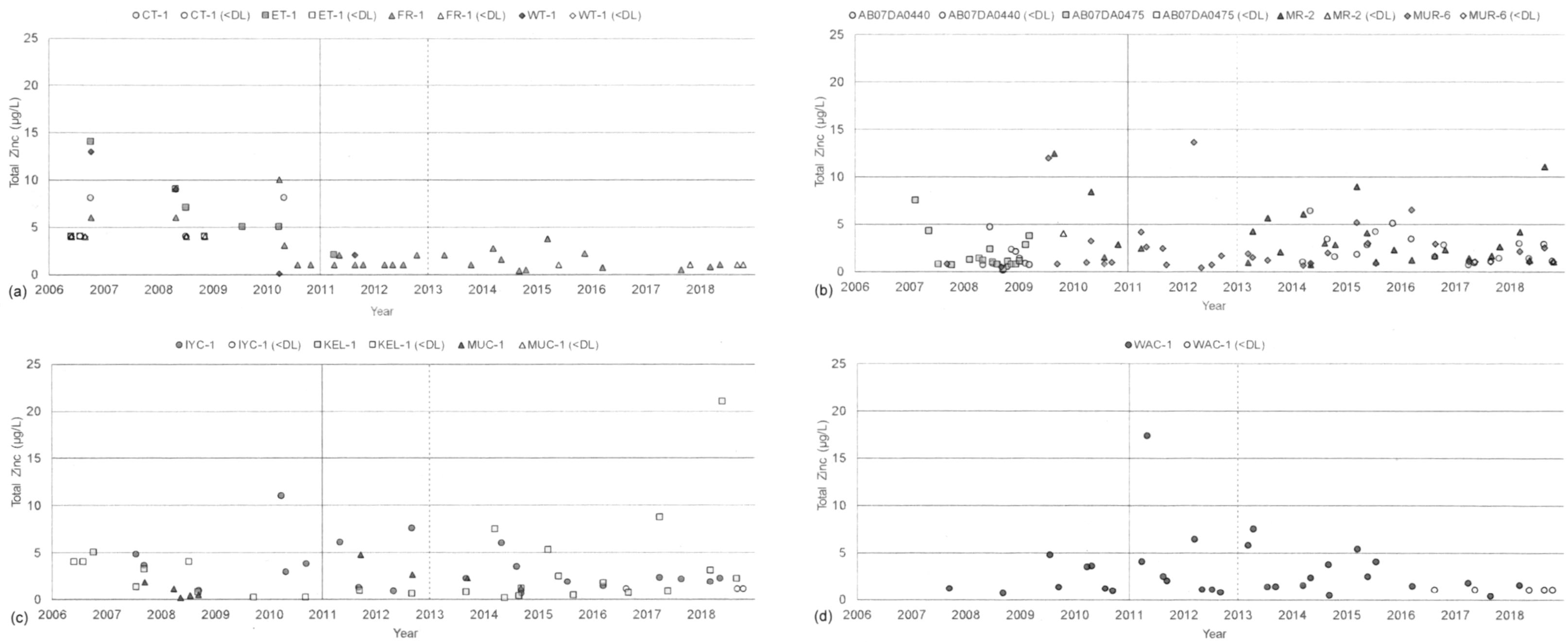
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-56 Time Series Plots of Total Uranium



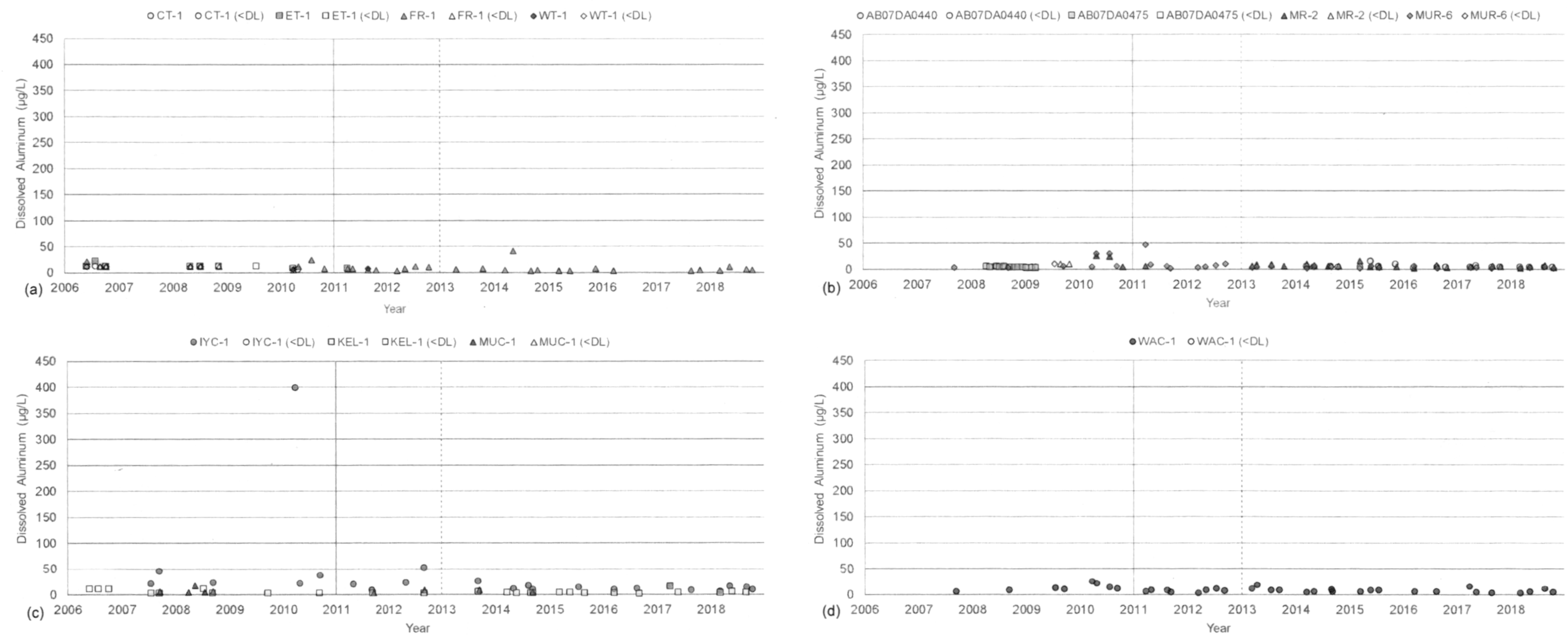
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-57 Time Series Plots of Total Vanadium



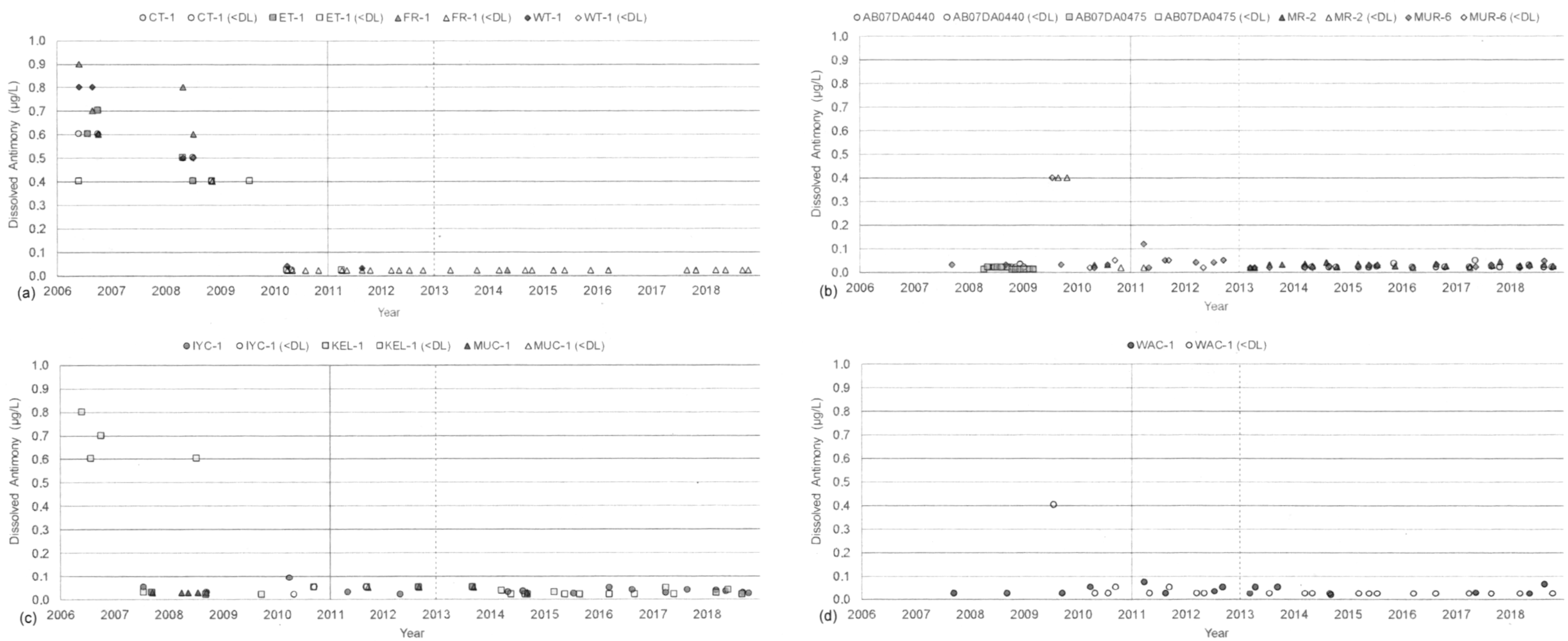
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-58 **Time Series Plots of Total Zinc**



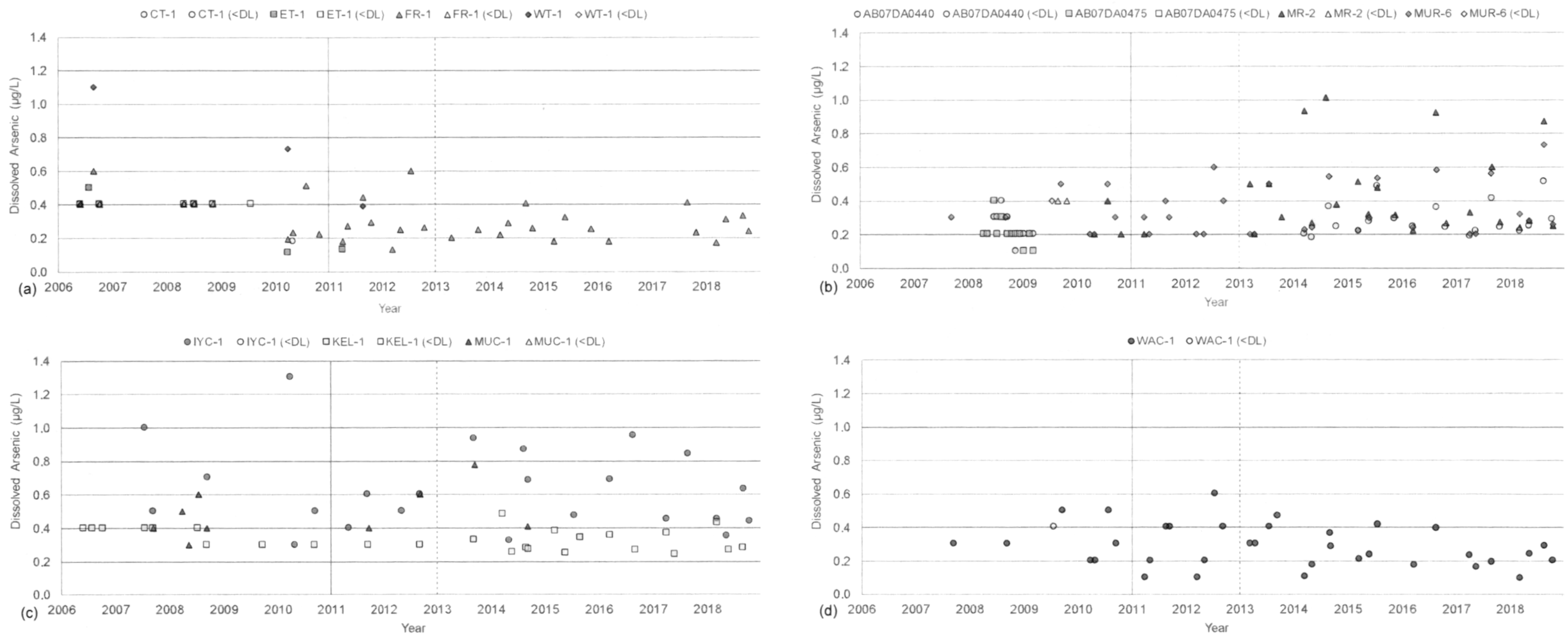
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-59 Time Series Plots of Dissolved Aluminum



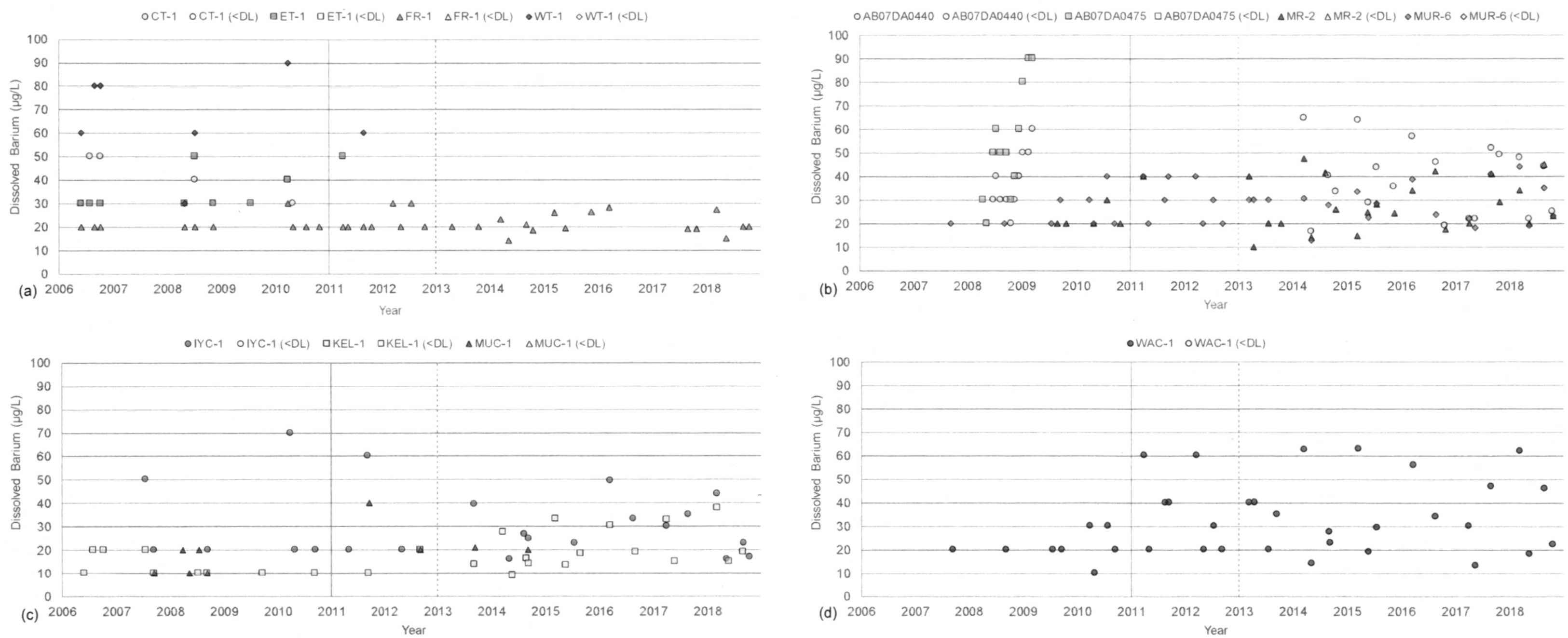
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-60 Time Series Plots of Dissolved Antimony



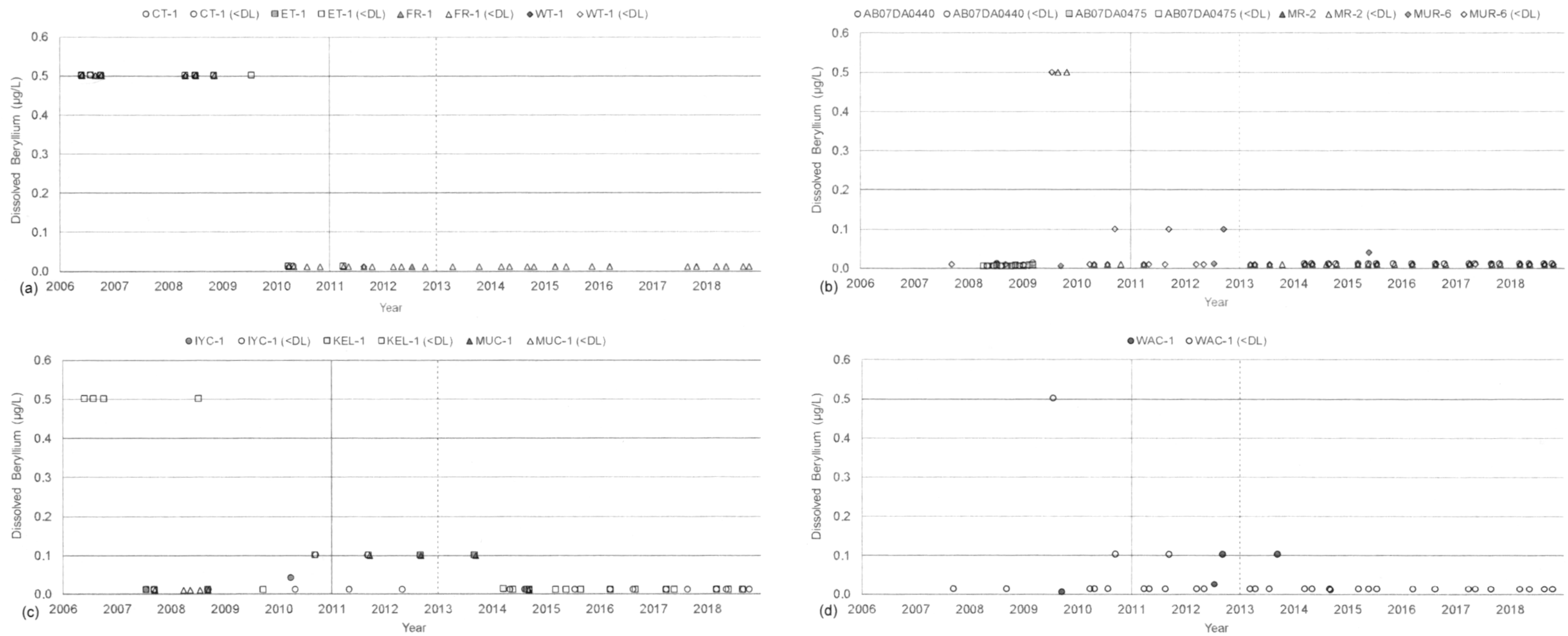
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-61 **Time Series Plots of Dissolved Arsenic**



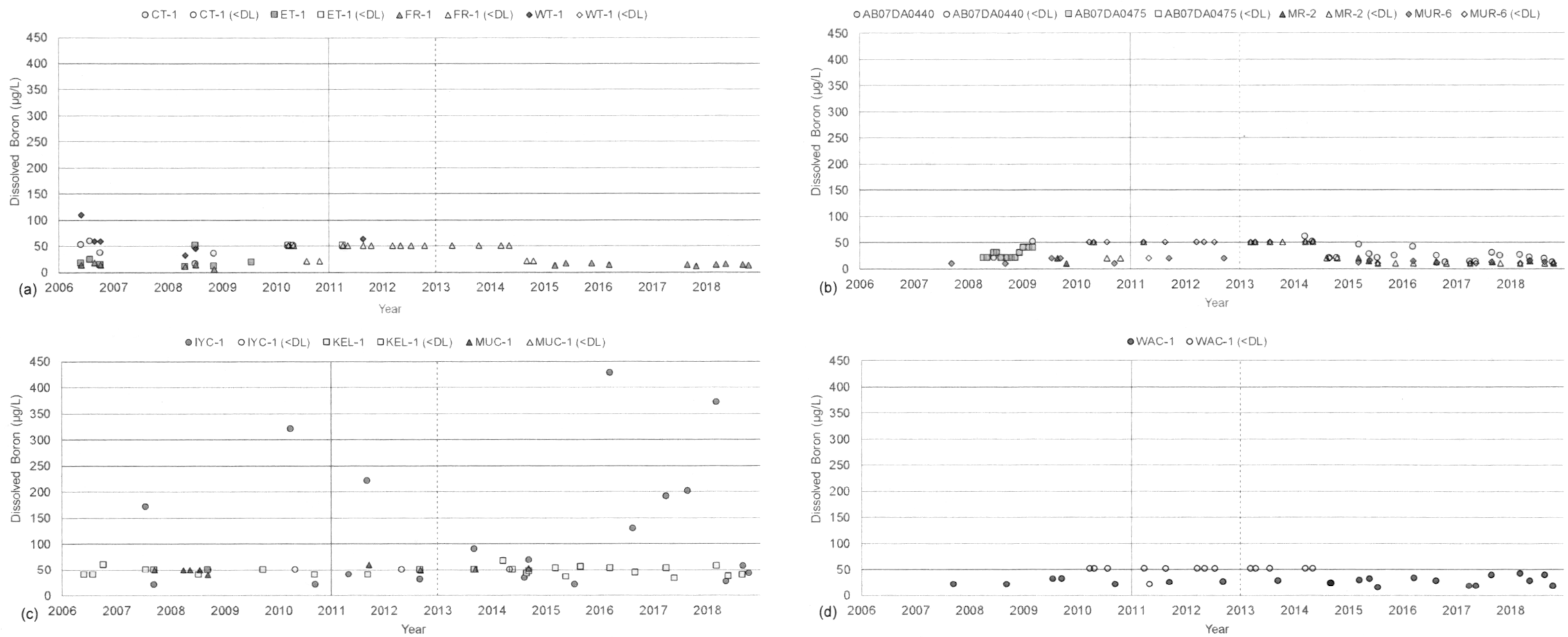
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-62 **Time Series Plots of Dissolved Barium**



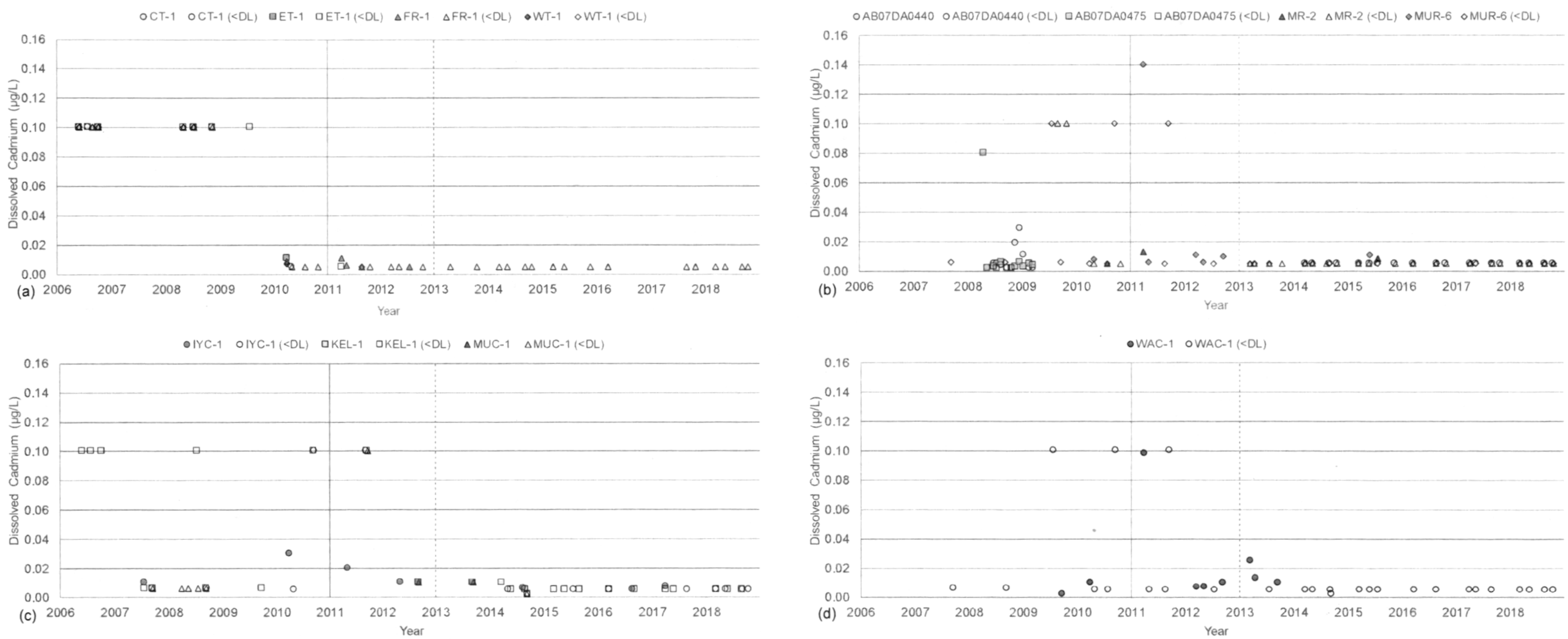
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-63 **Time Series Plots of Dissolved Beryllium**



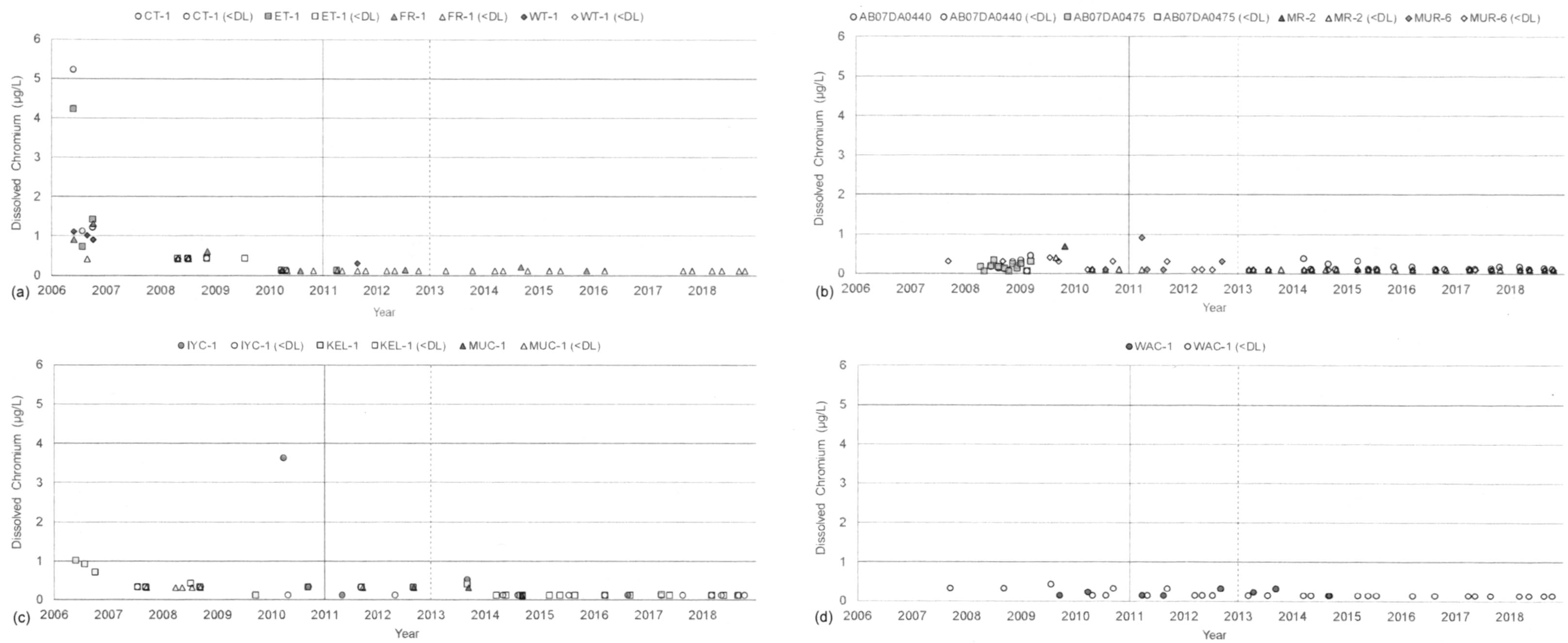
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-64 **Time Series Plots of Dissolved Boron**



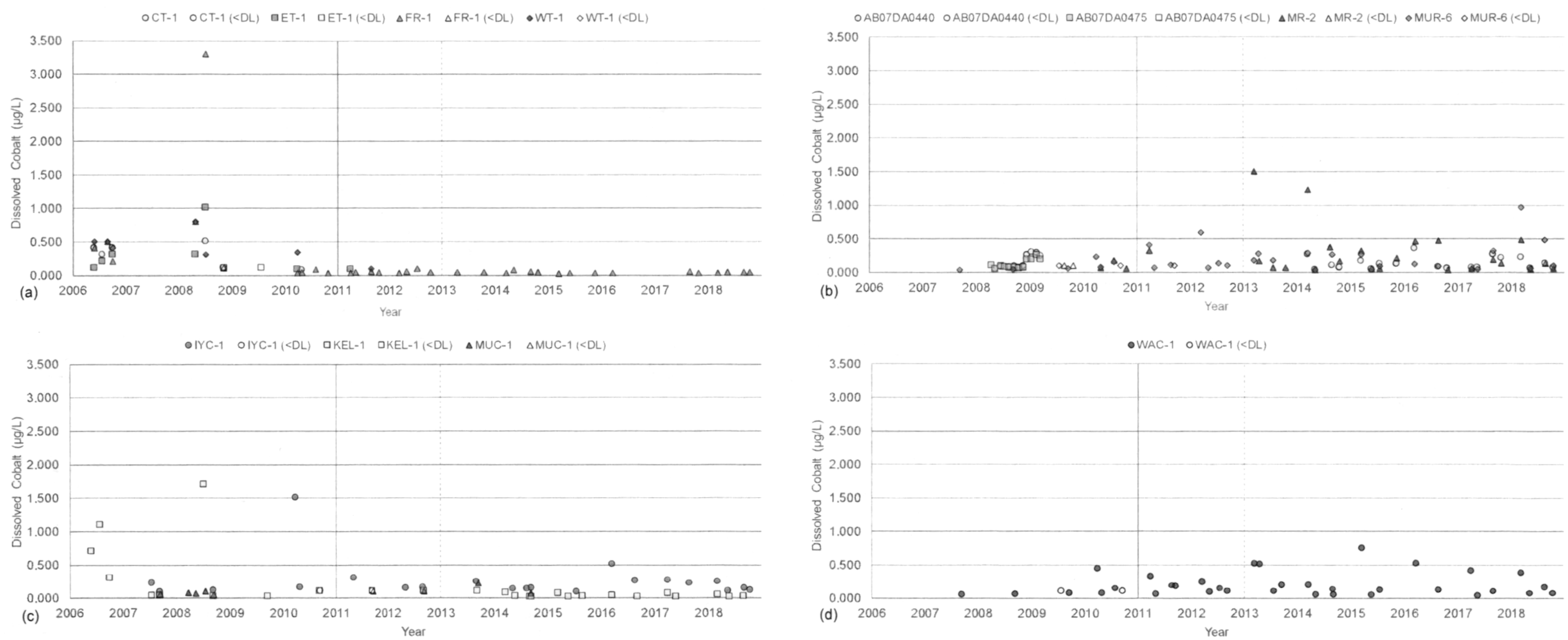
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-65 **Time Series Plots of Dissolved Cadmium**



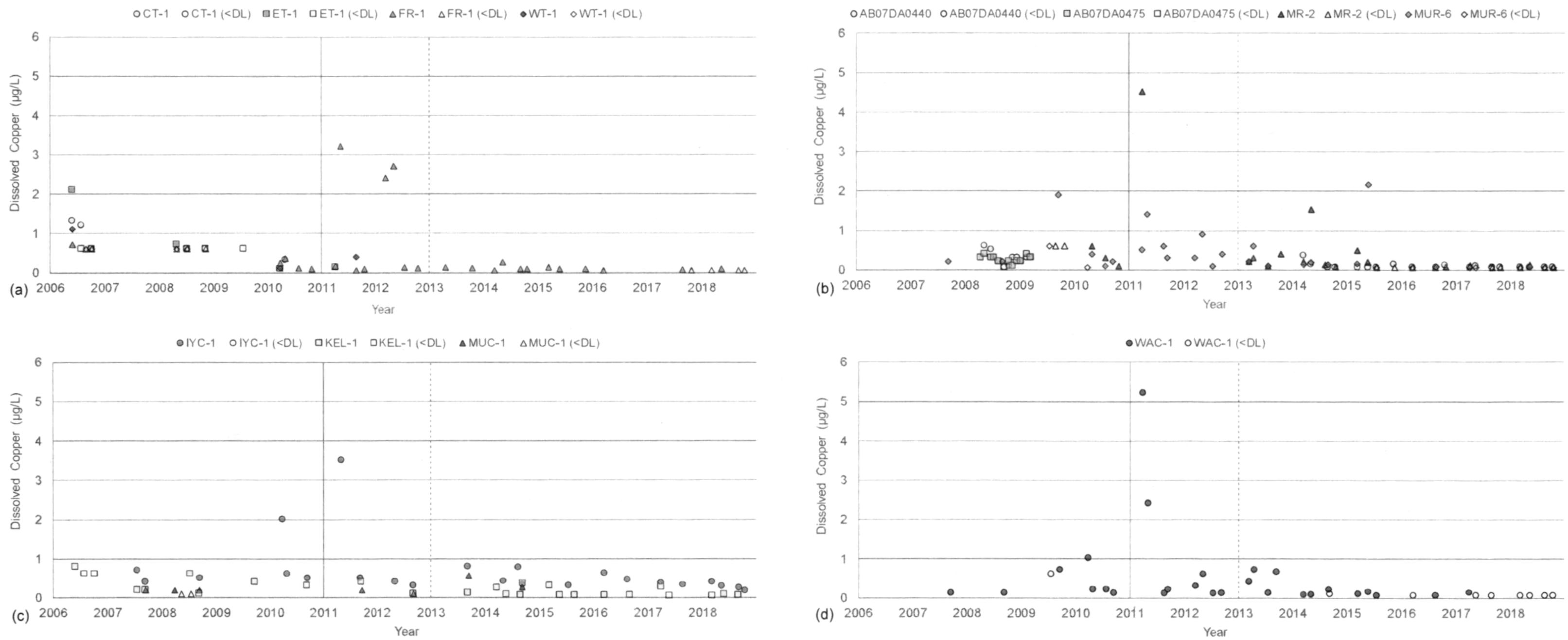
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-66 **Time Series Plots of Dissolved Chromium**



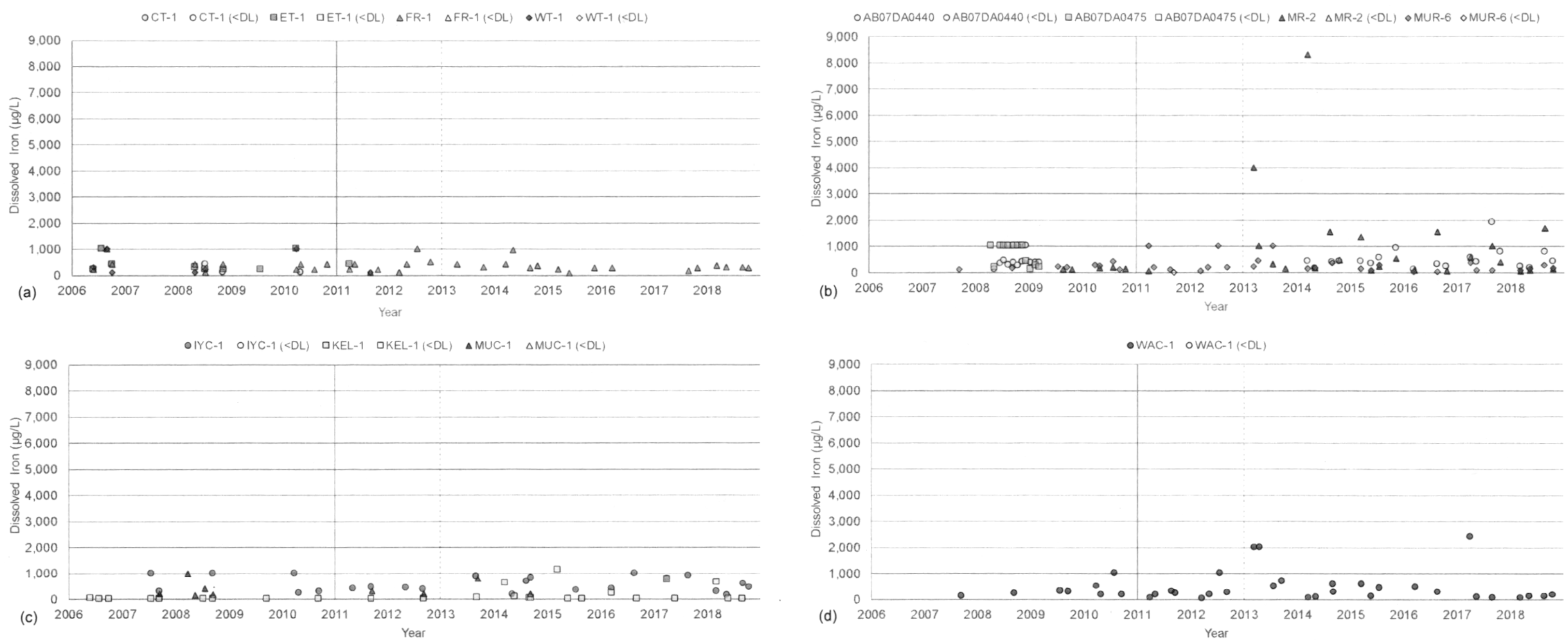
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-67 Time Series Plots of Dissolved Cobalt



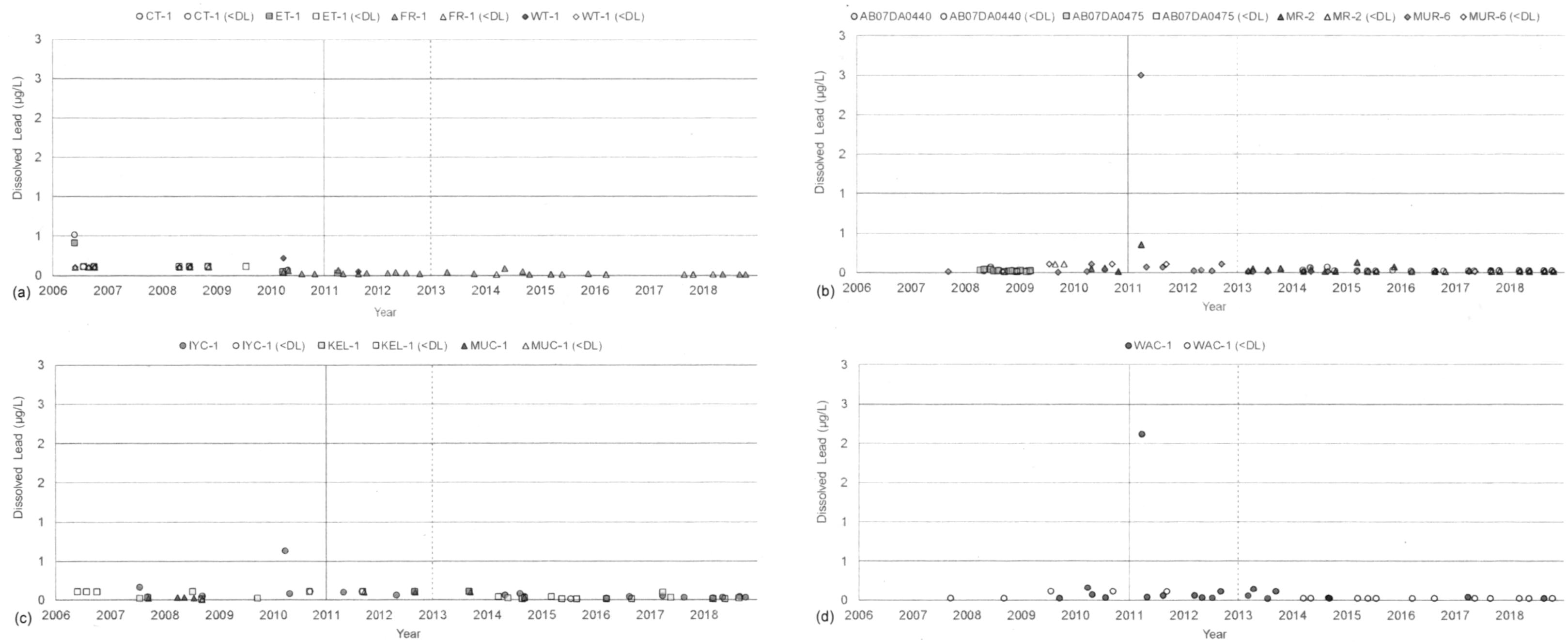
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-68 Time Series Plots of Dissolved Copper



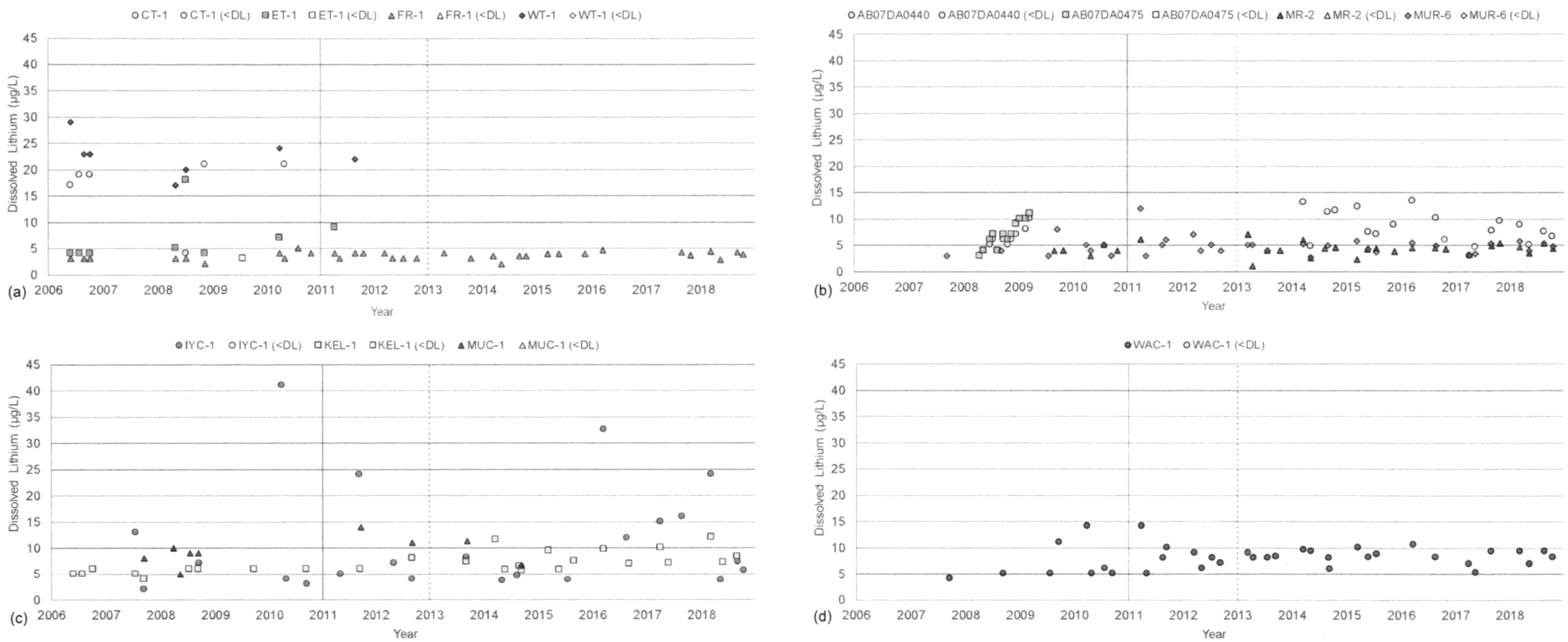
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-69 Time Series Plots of Dissolved Iron



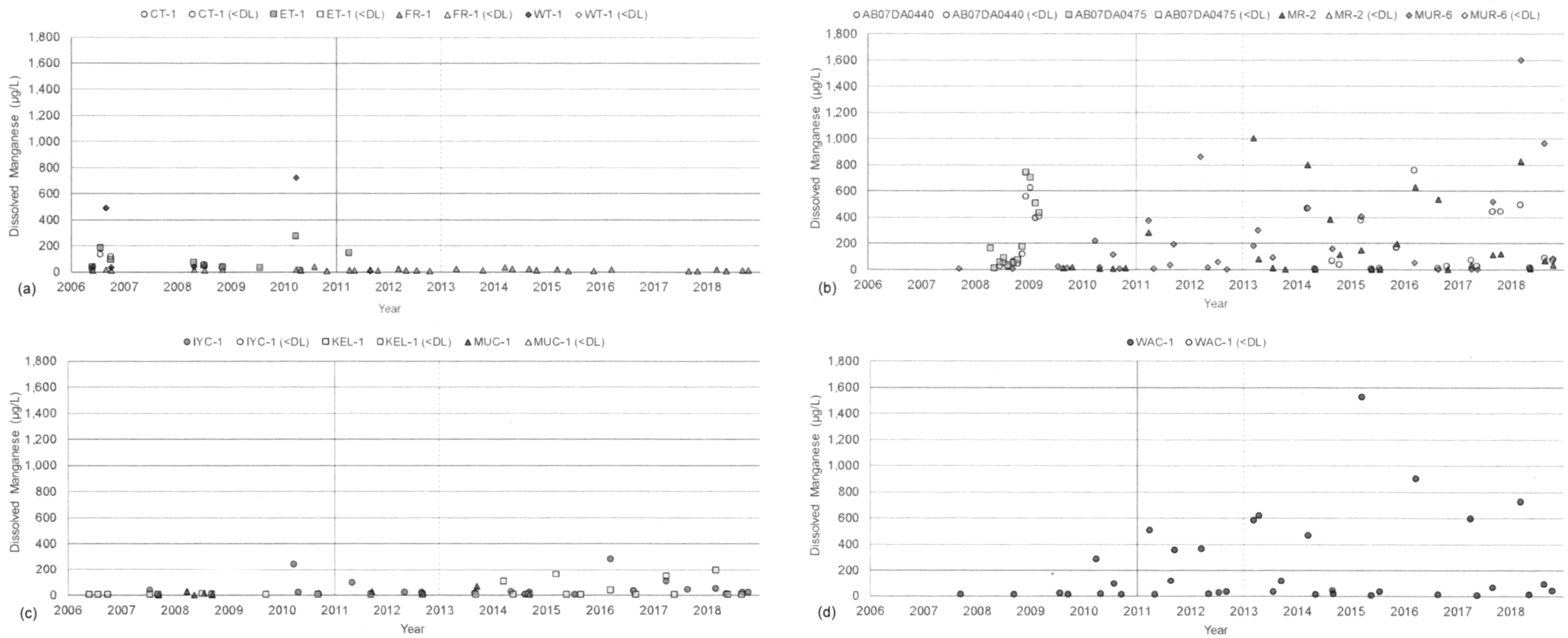
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-70 Time Series Plots of Dissolved Lead



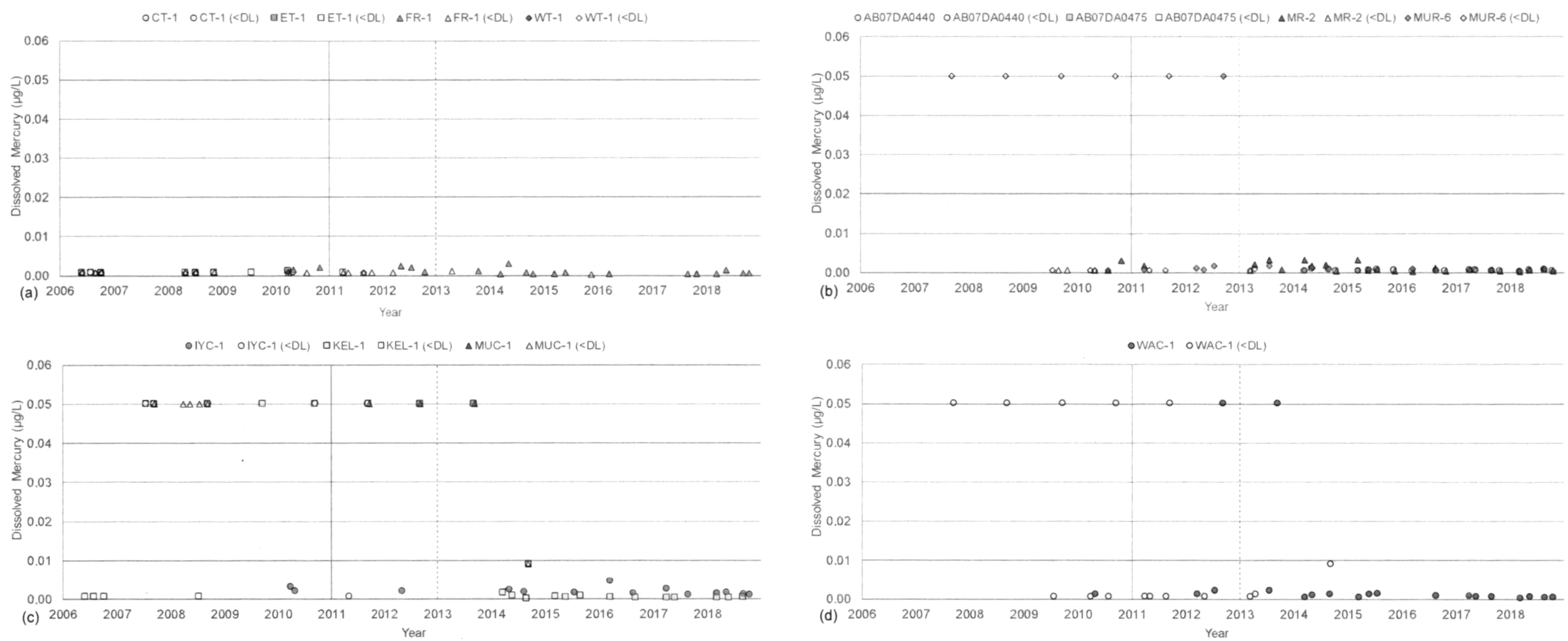
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-71 Time Series Plots of Dissolved Lithium



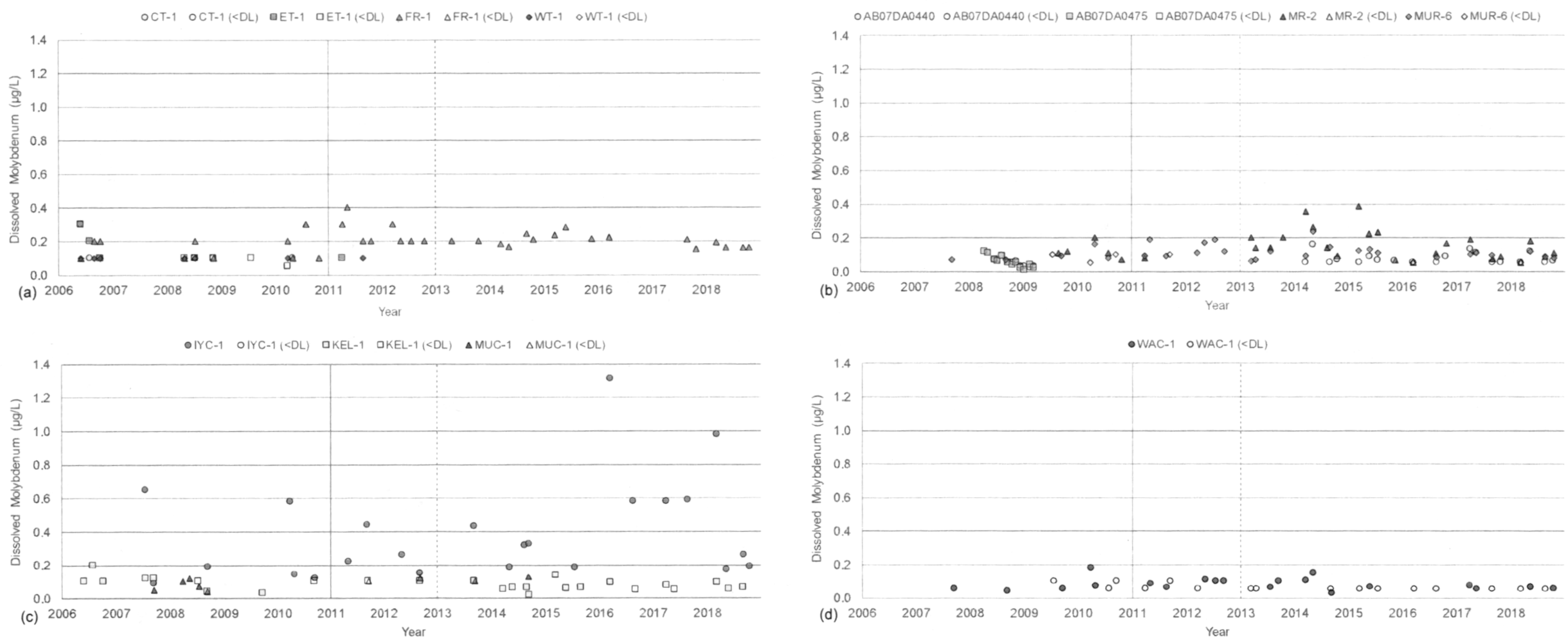
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-72 **Time Series Plots of Dissolved Manganese**



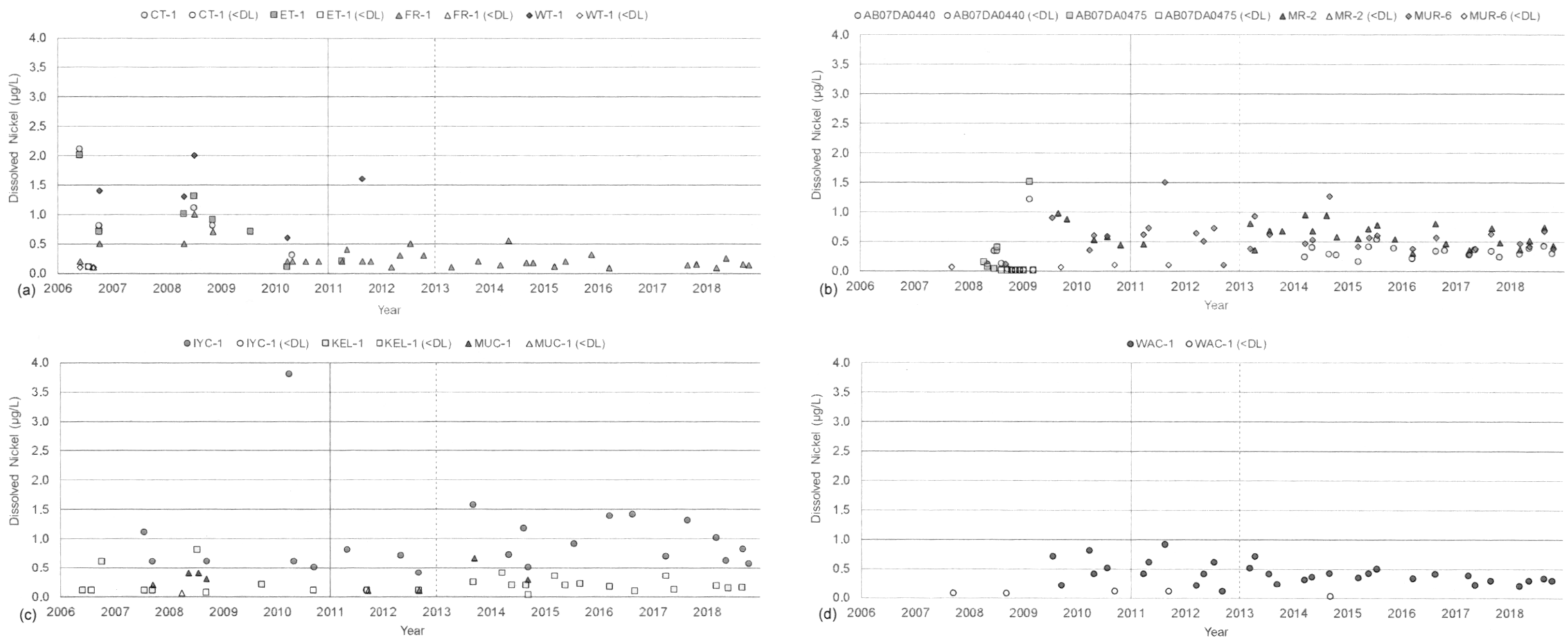
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-73 Time Series Plots of Dissolved Mercury



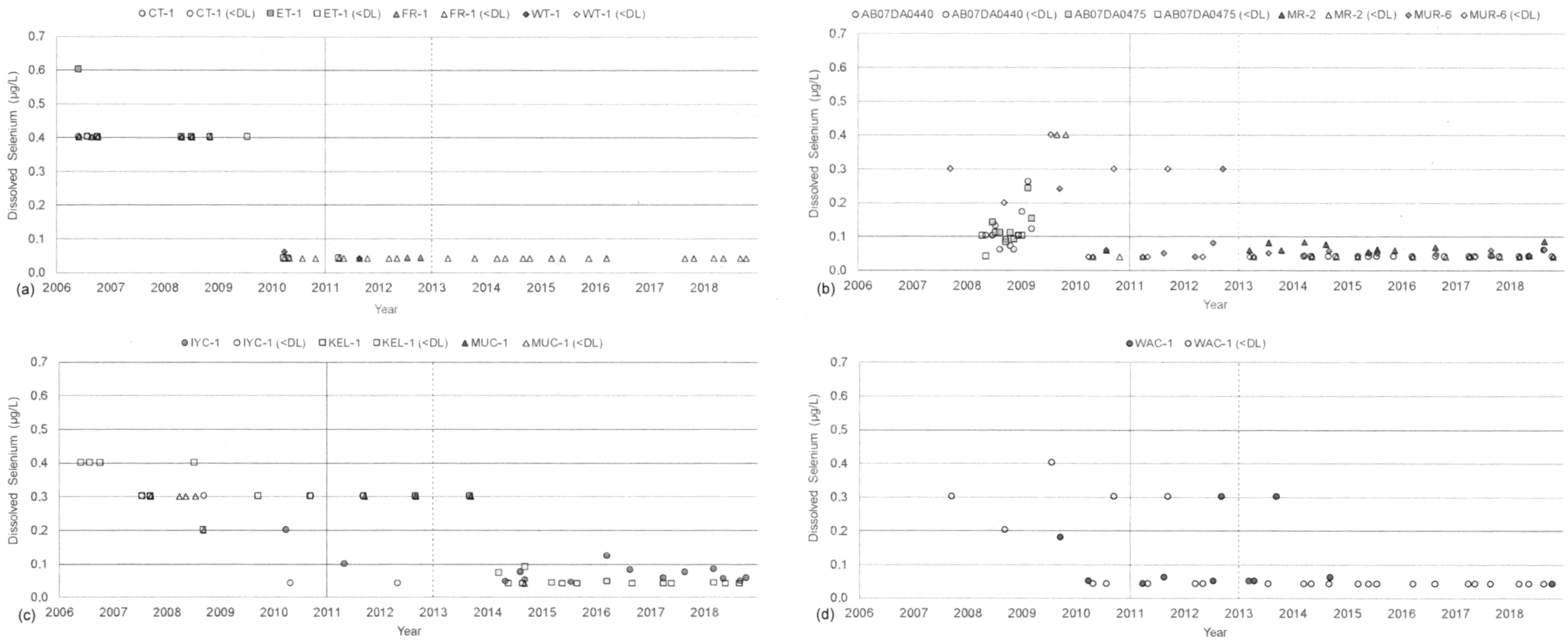
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-74 Time Series Plots of Dissolved Molybdenum



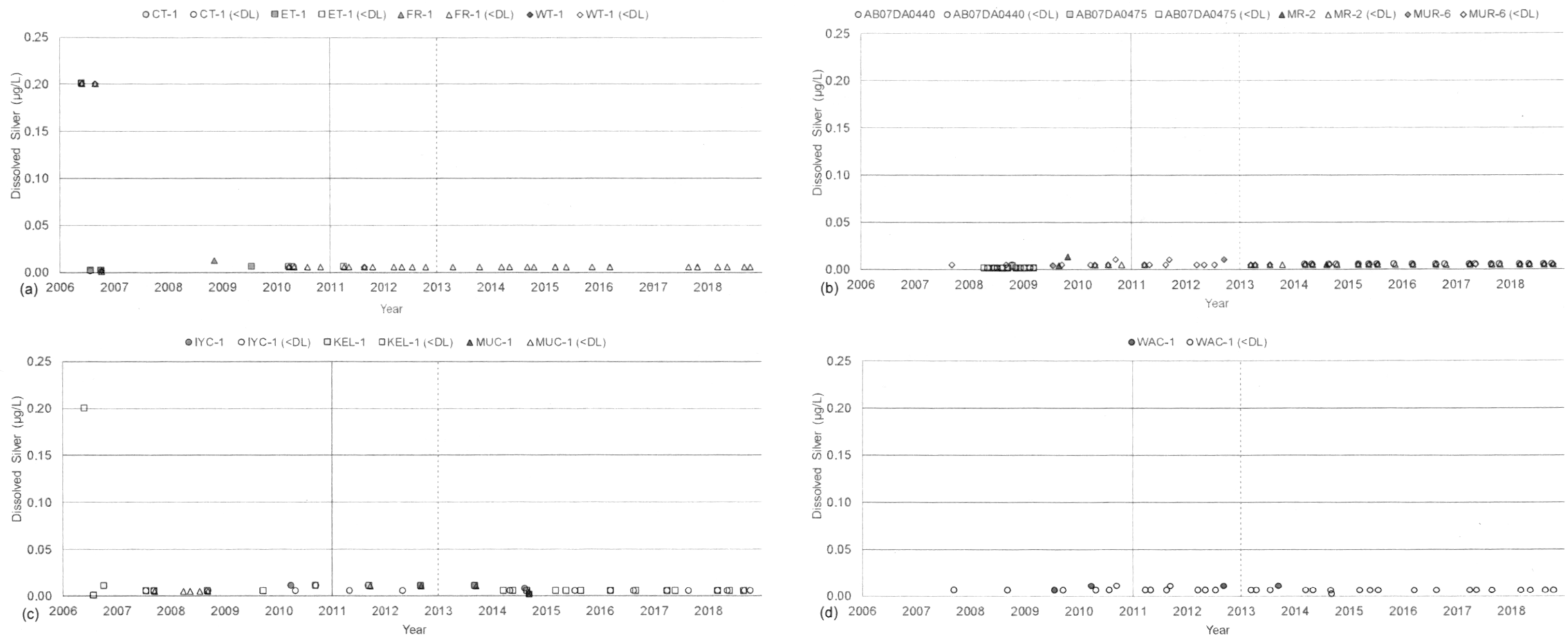
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-75 **Time Series Plots of Dissolved Nickel**



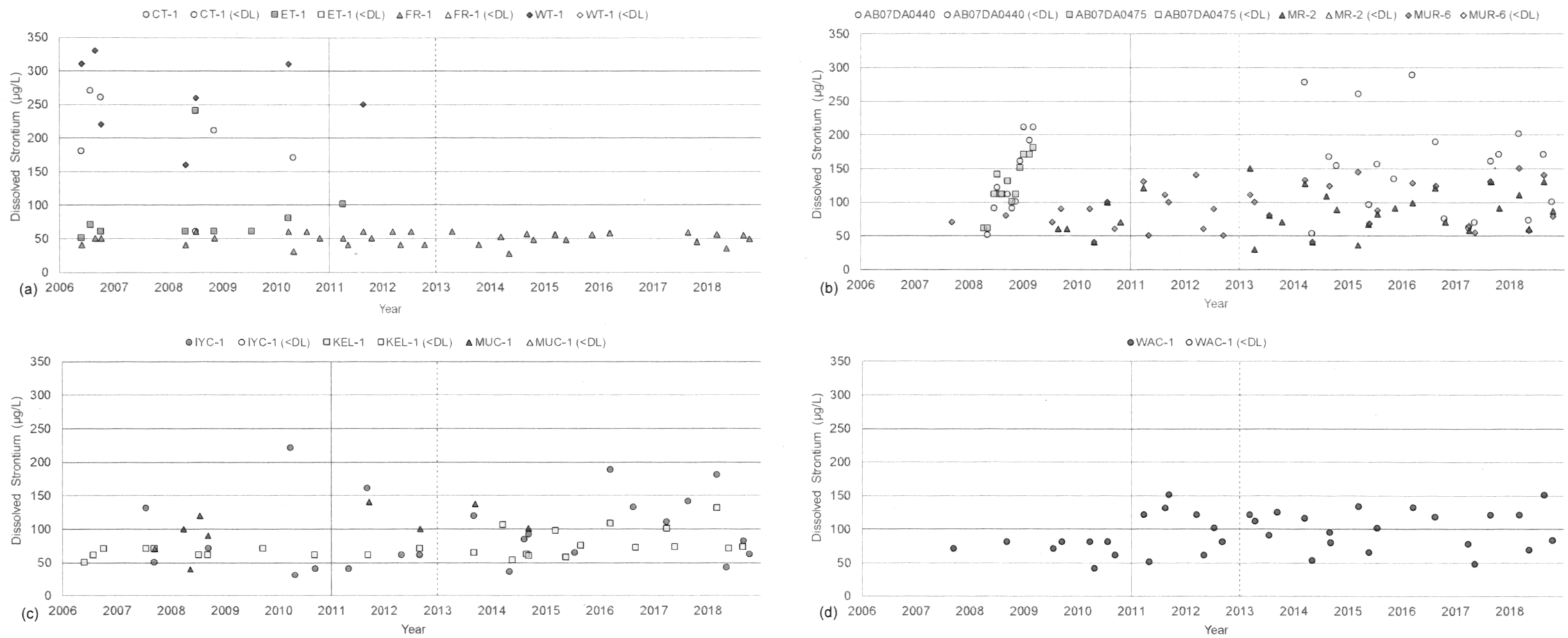
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-76 **Time Series Plots of Dissolved Selenium**



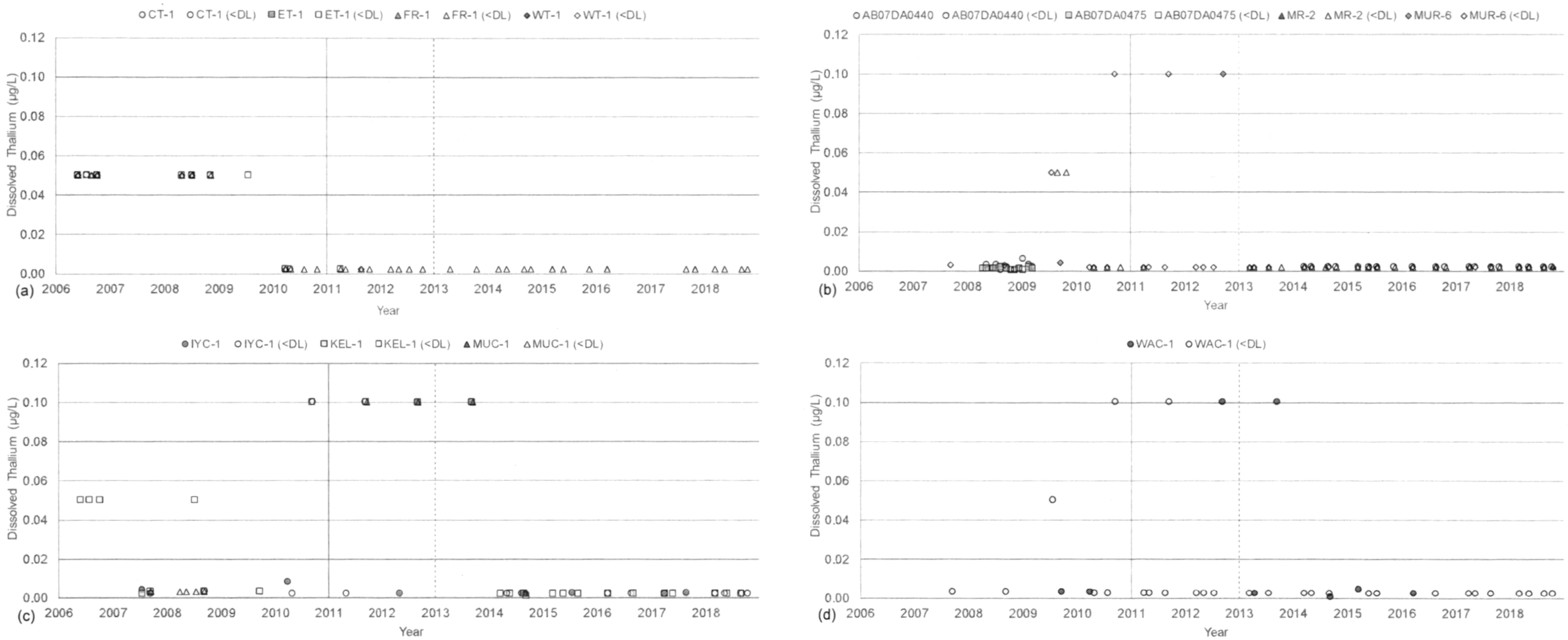
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-77 **Time Series Plots of Dissolved Silver**



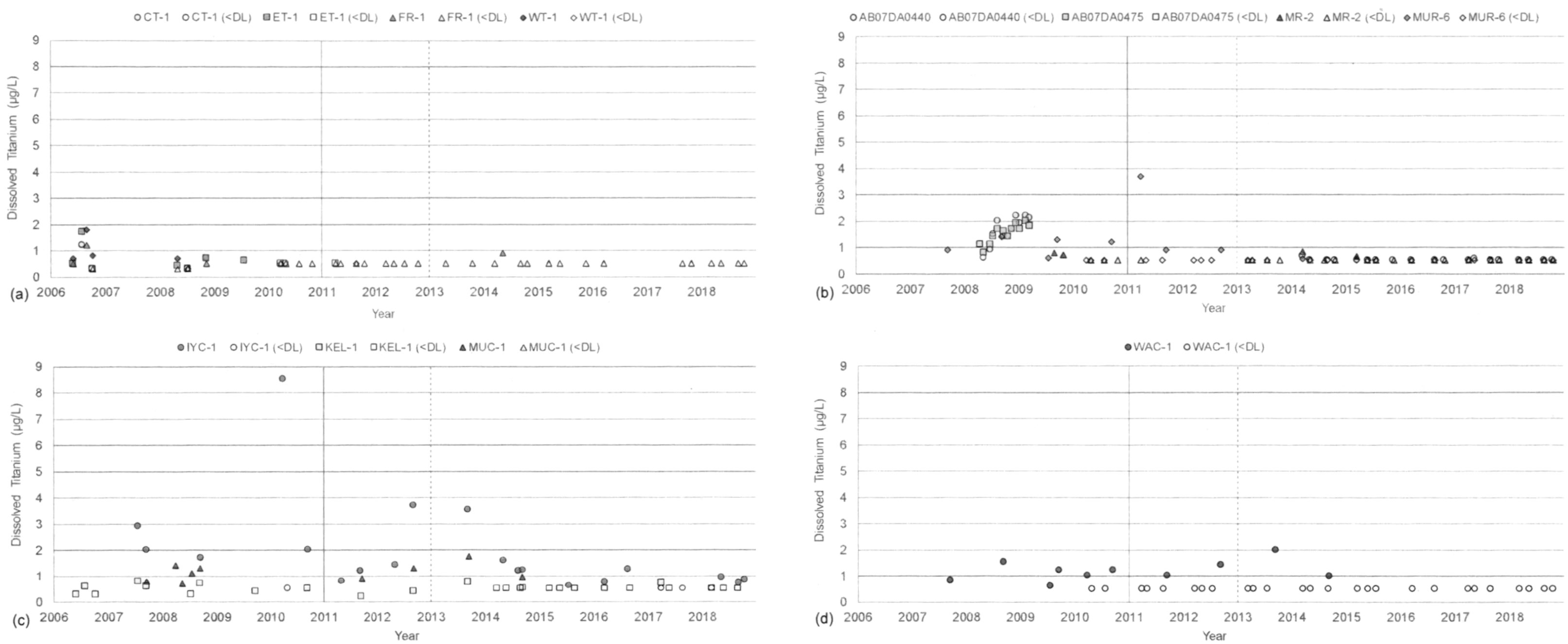
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-78 **Time Series Plots of Dissolved Strontium**



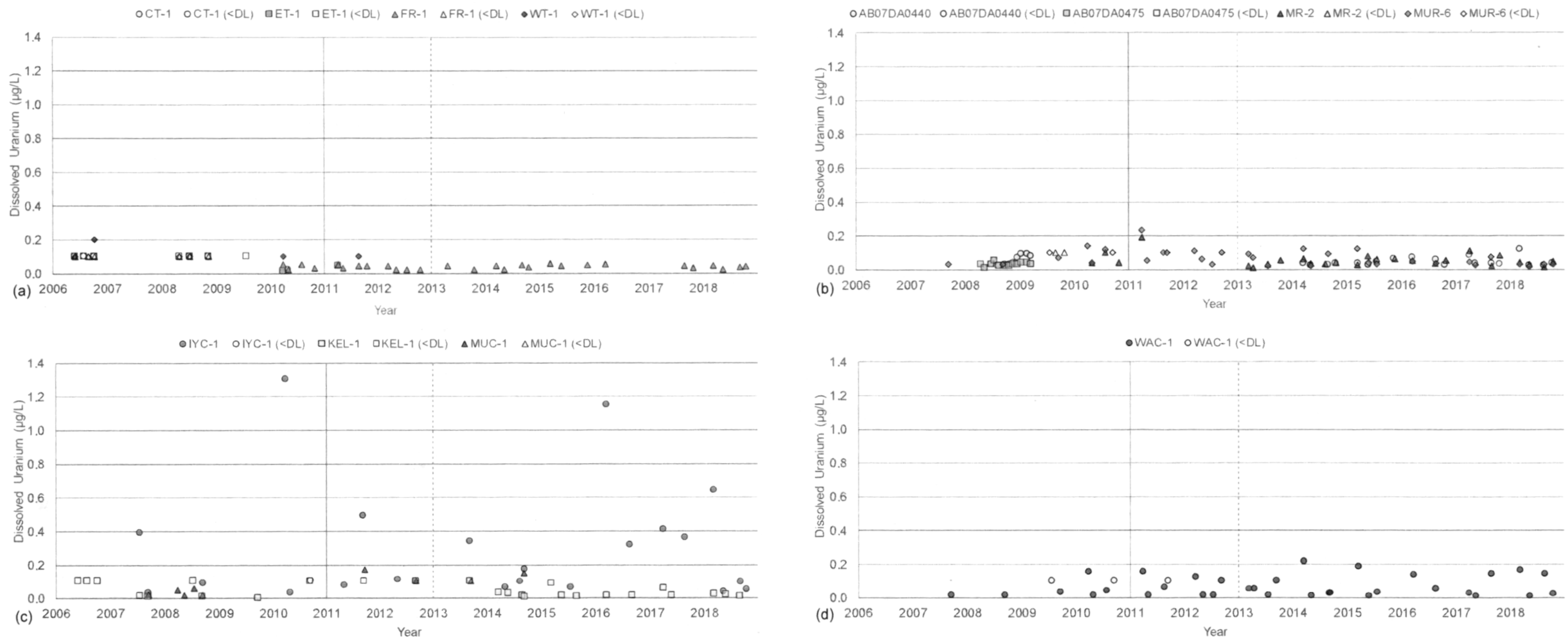
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-79 **Time Series Plots of Dissolved Thallium**



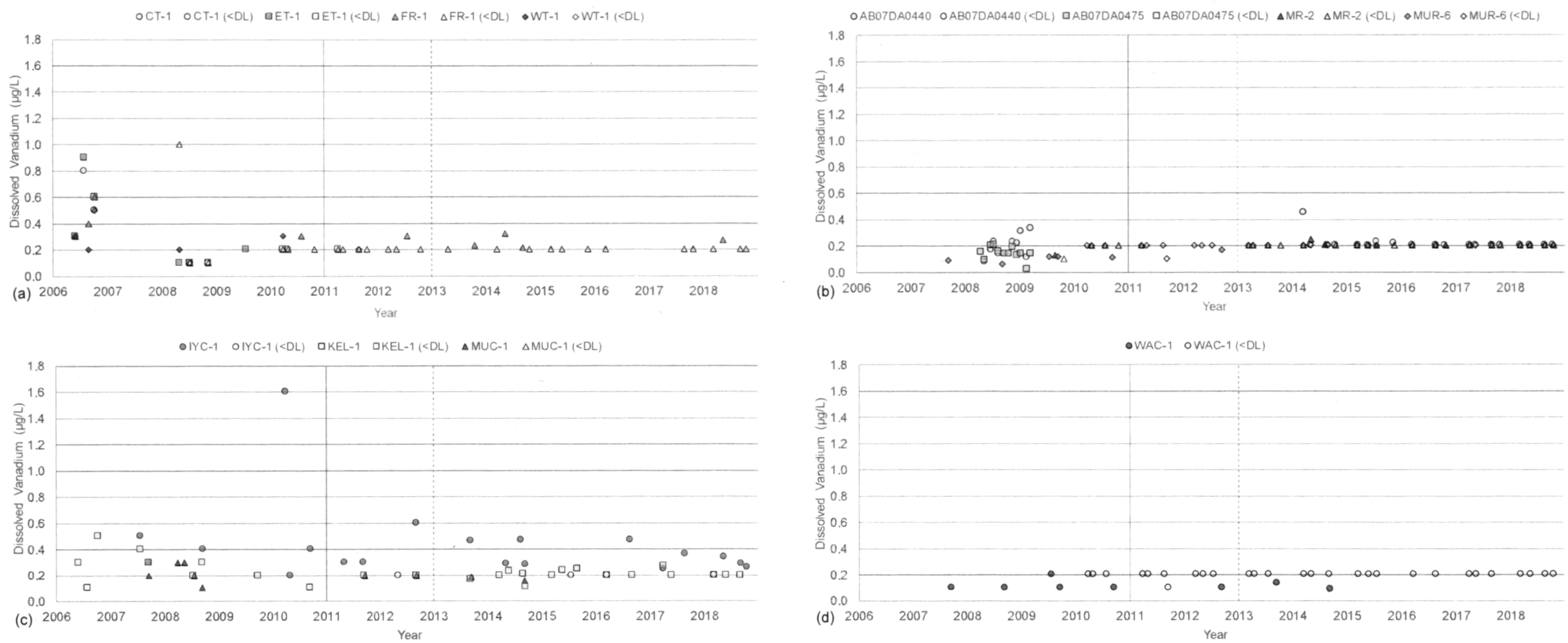
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-80 **Time Series Plots of Dissolved Titanium**



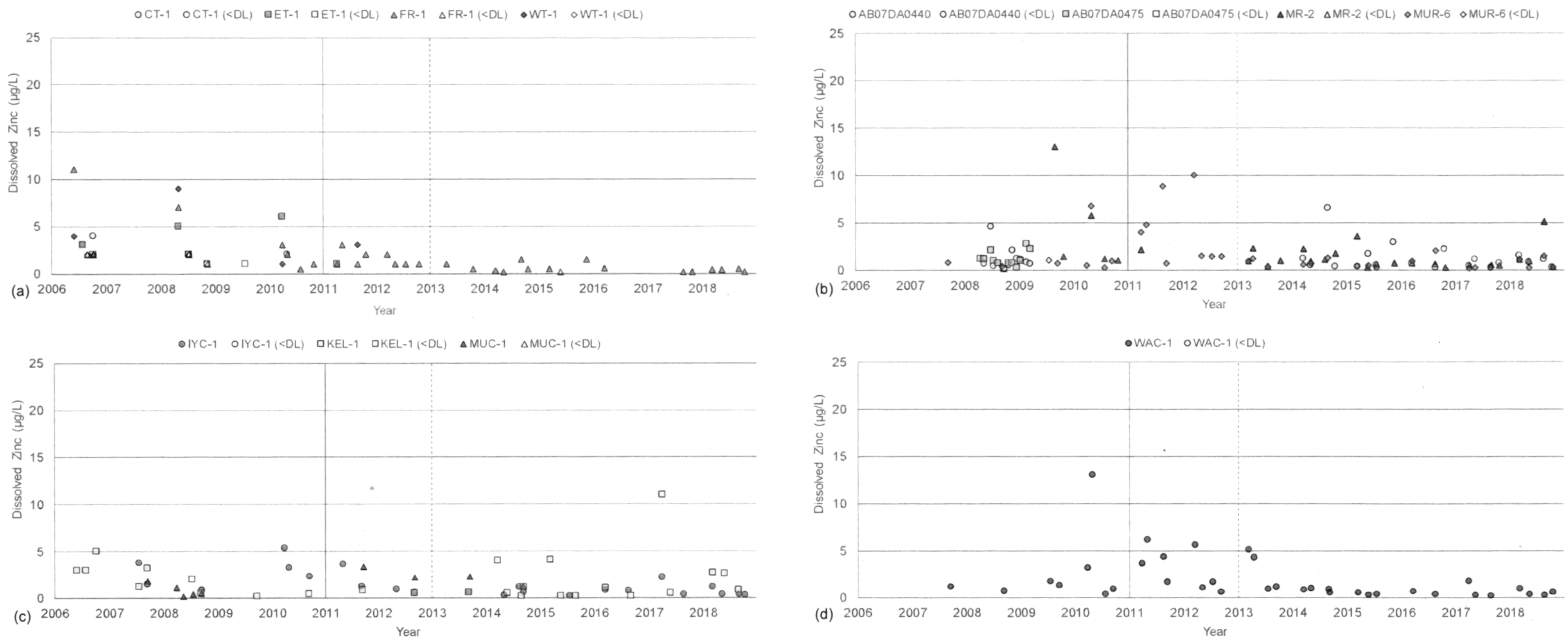
Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-81 **Time Series Plots of Dissolved Uranium**



Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-82 **Time Series Plots of Dissolved Vanadium**



Panel (a) includes Firebag River watershed stations (Stations CT-1, ET-1, FR-1, and WT-1), panel (b) includes Muskeg River watershed stations (Stations AB07DA0440, AB07DA0475, MR-2, and MUR-6,), panel (c) includes Muskeg Creek watershed stations (Stations IYC-1, KEL-1 and MUC-1), and panel (d) includes Wapasu Creek watershed stations (Station WAC-1).
DL = detection limit; < = less than.

Figure VII-83 Time Series Plots of Dissolved Zinc

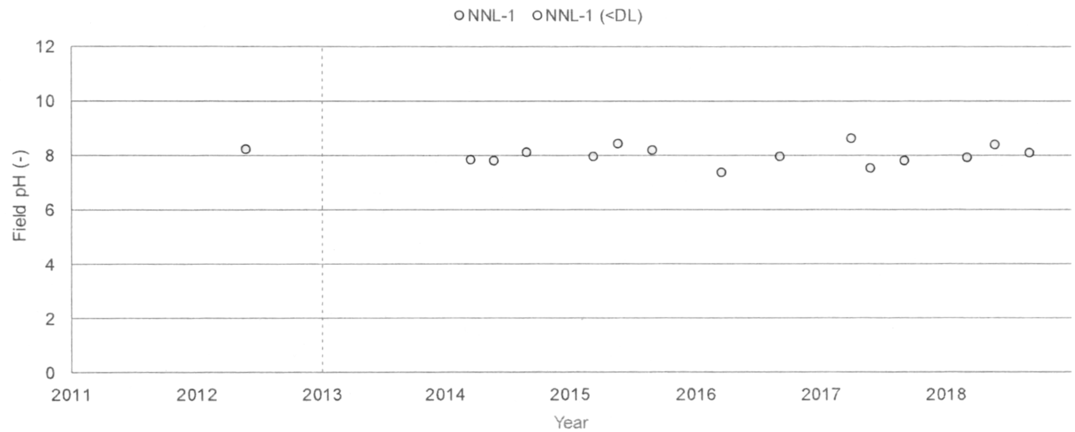
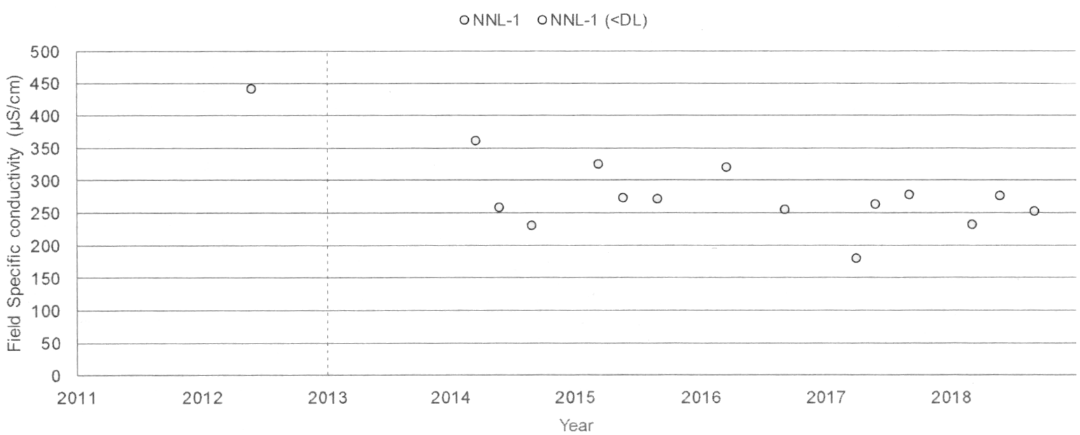
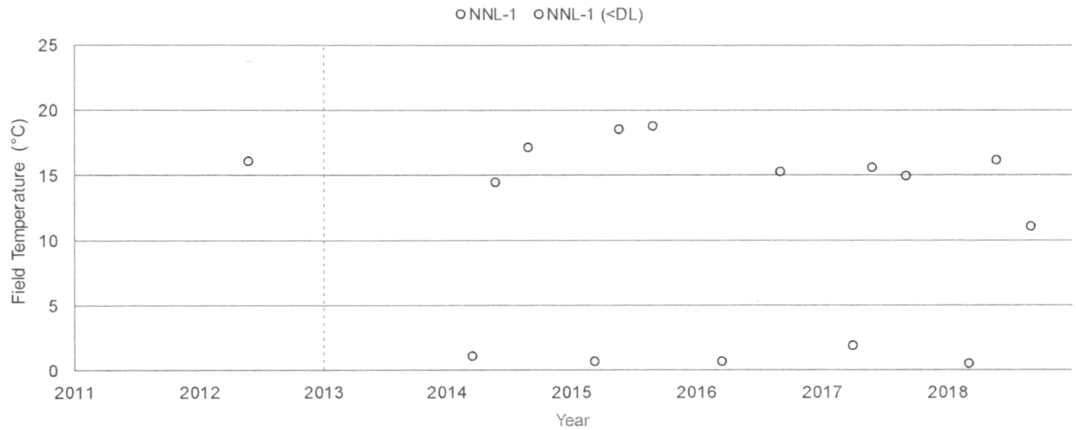


Figure VII-84 Time Series Plot at Station NNL-1 for Field Measured pH



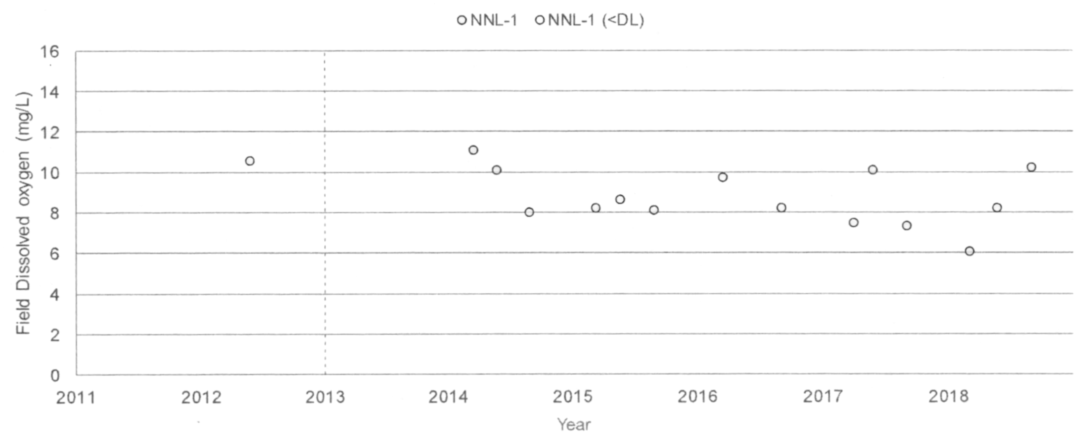
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure VII-85 Time Series Plot at Station NNL-1 for Field Measured Specific Conductivity



DL = detection limit; < = less than.

Figure VII-86 **Time Series Plot at Station NNL-1 for Field Measured Temperature**



DL = detection limit; < = less than.

Figure VII-87 **Time Series Plot at Station NNL-1 for Field Measured Dissolved Oxygen**

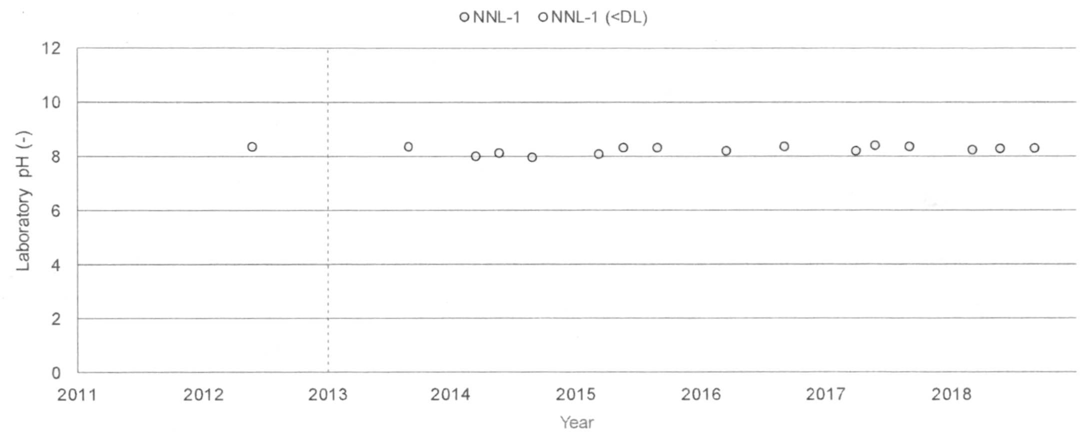
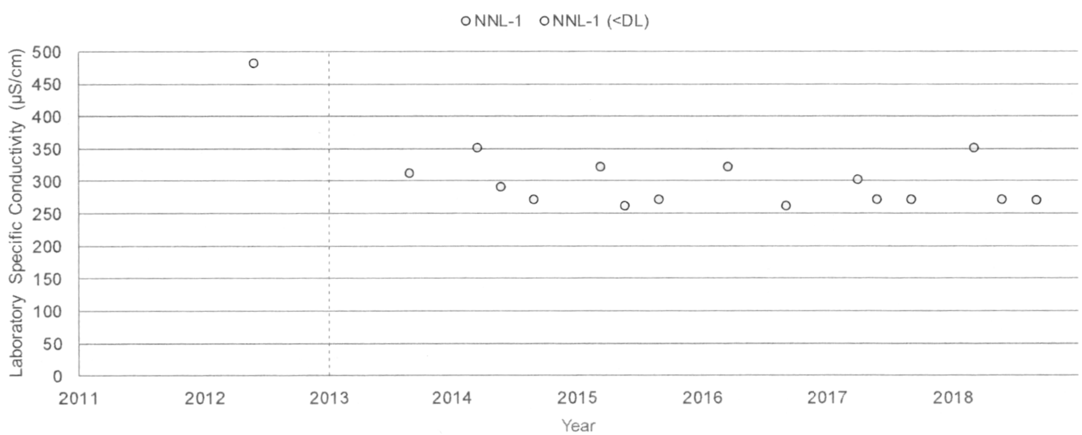
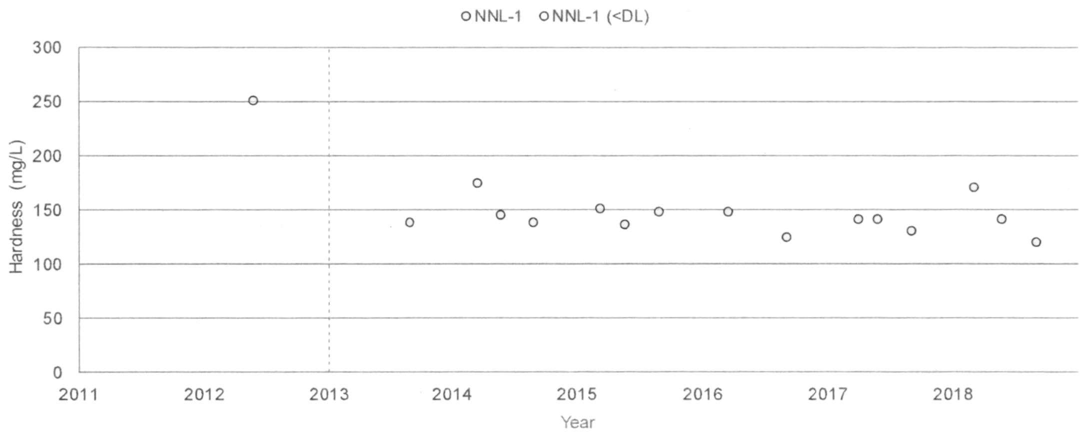


Figure VII-88 Time Series Plot at Station NNL-1 for Laboratory pH



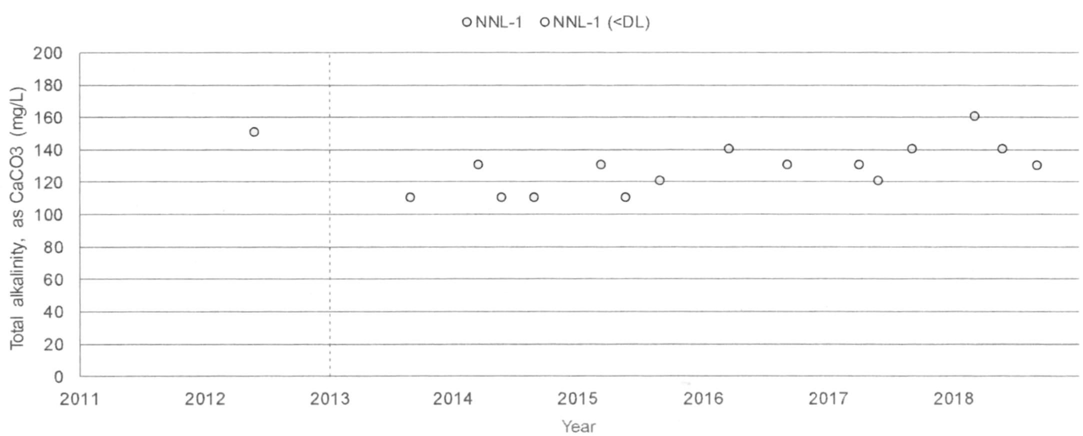
µS/cm = microSiemens per centimetre; DL = detection limit; < = less than.

Figure VII-89 Time Series Plot at Station NNL-1 for Laboratory Specific Conductivity



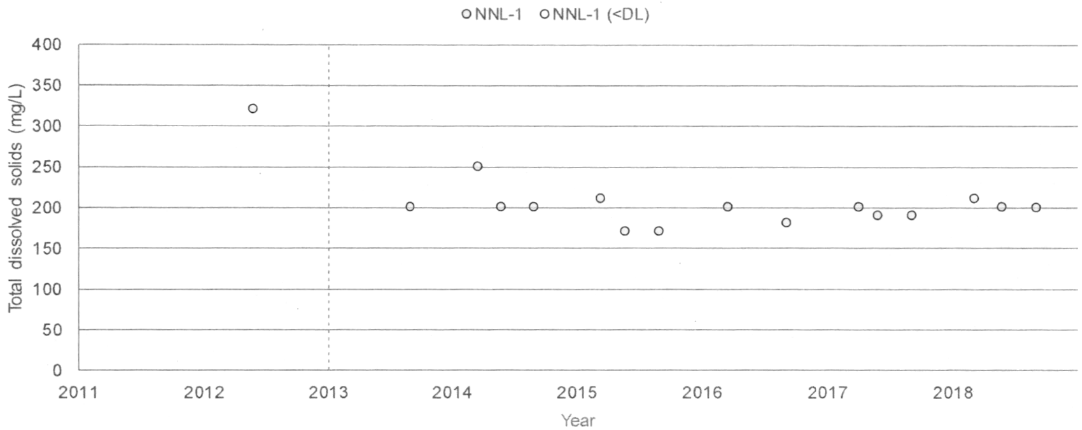
DL = detection limit; < = less than.

Figure VII-90 **Time Series Plot at Station NNL-1 for Hardness**



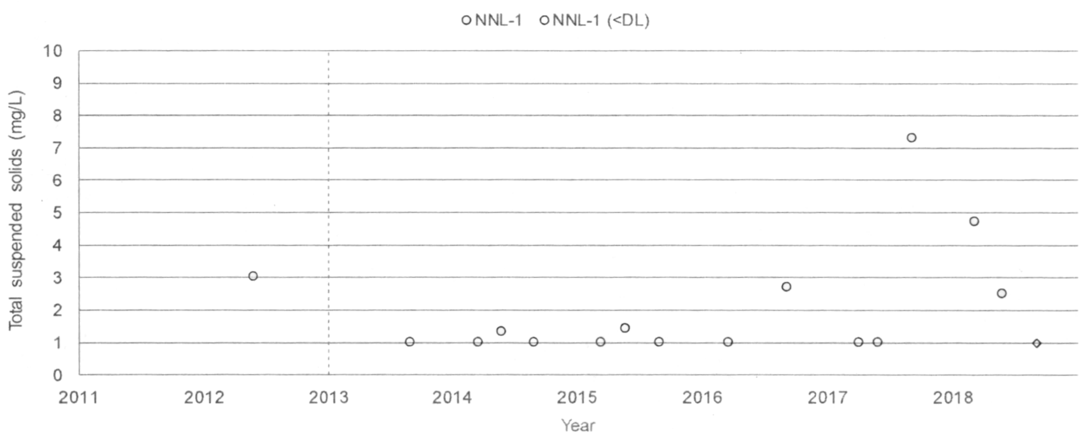
DL = detection limit; < = less than.

Figure VII-91 **Time Series Plot at Station NNL-1 for Total Alkalinity, as $CaCO_3$**



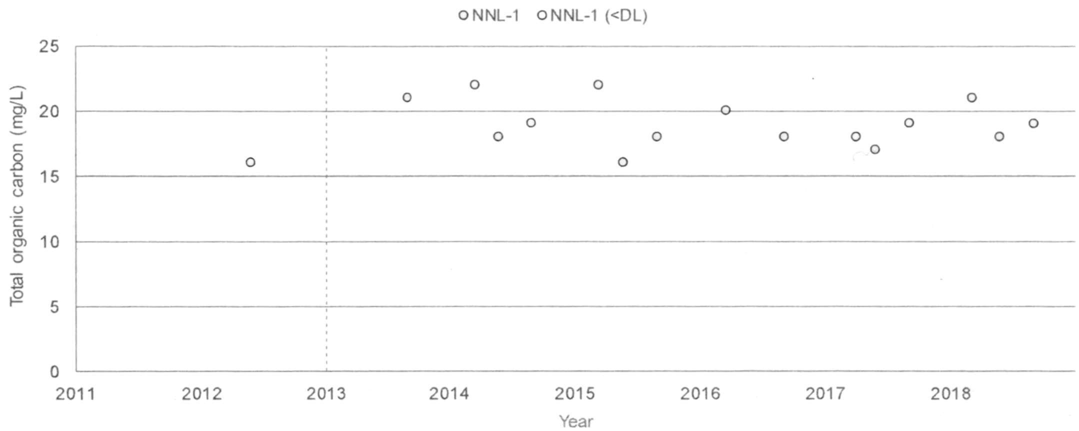
DL = detection limit; < = less than.

Figure VII-92 Time Series Plot at Station NNL-1 for Total Dissolved Solids



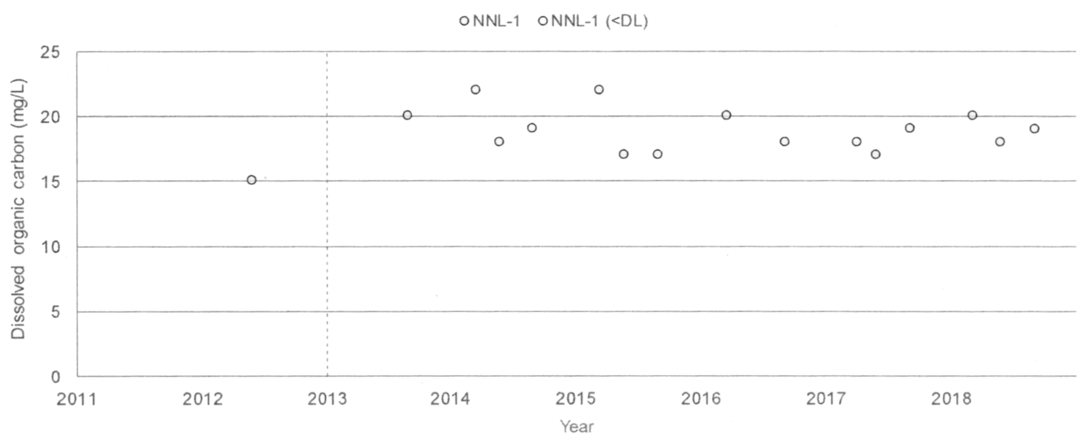
DL = detection limit; < = less than.

Figure VII-93 Time Series Plot at Station NNL-1 for Total Suspended Solids



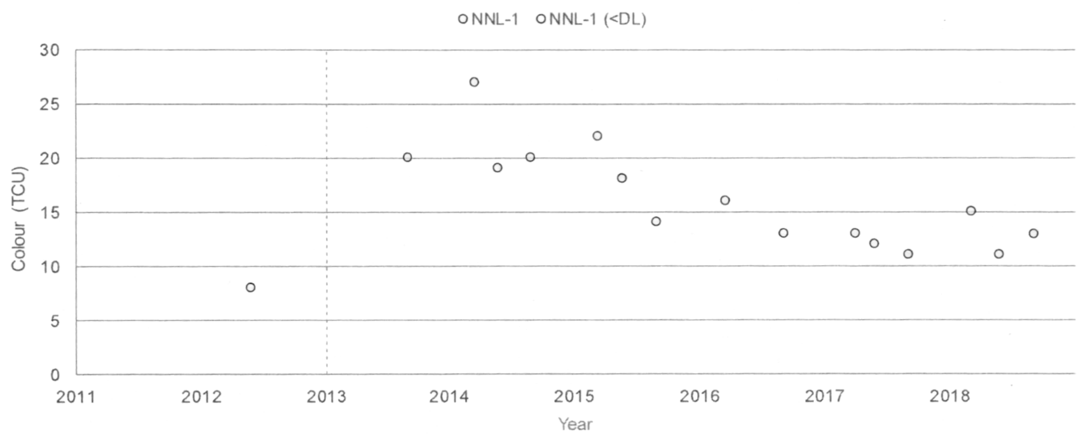
DL = detection limit; < = less than.

Figure VII-94 **Time Series Plot at Station NNL-1 for Total Organic Carbon**



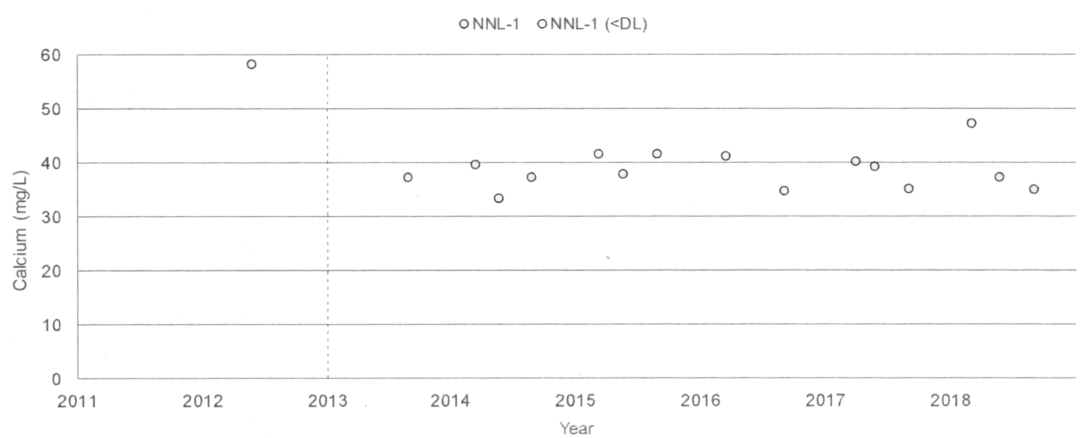
DL = detection limit; < = less than.

Figure VII-95 **Time Series Plot at Station NNL-1 for Dissolved Organic Carbon**



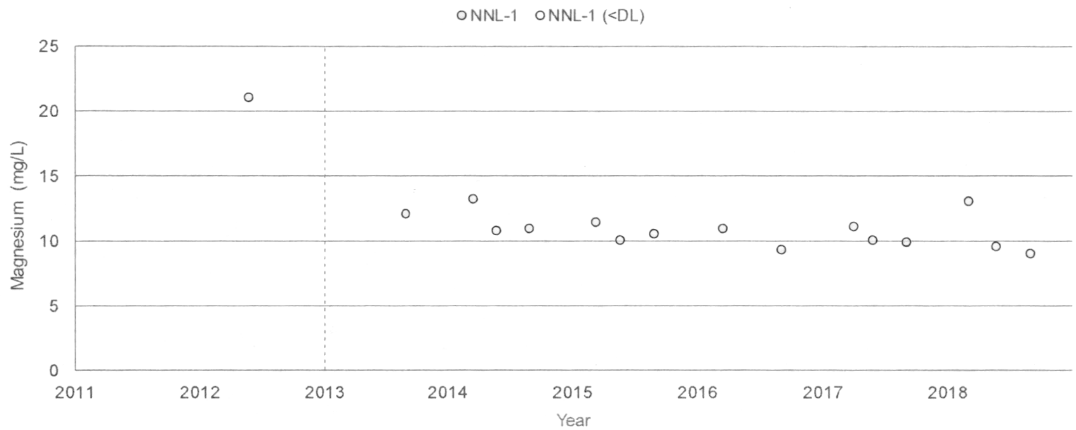
DL = detection limit; < = less than.

Figure VII-96 Time Series Plot at Station NNL-1 for Colour



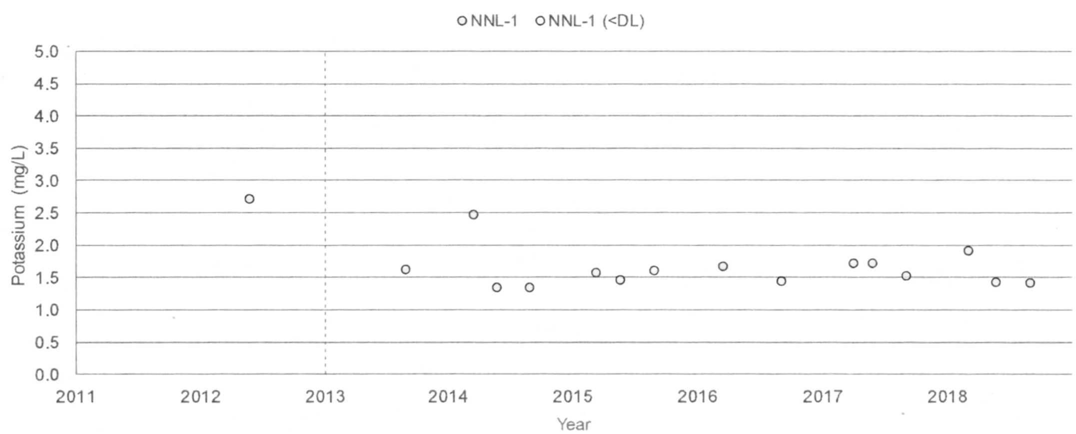
DL = detection limit; < = less than.

Figure VII-97 Time Series Plot at Station NNL-1 for Calcium



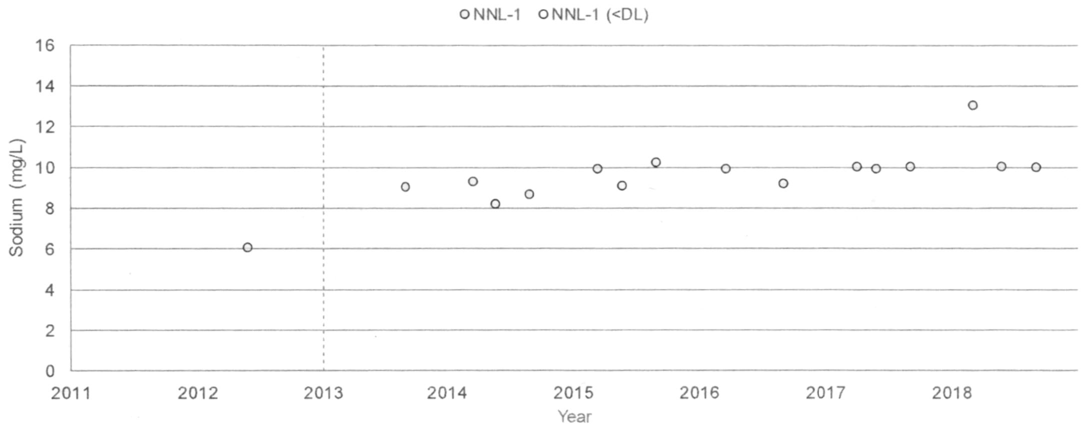
DL = detection limit; < = less than.

Figure VII-98 **Time Series Plot at Station NNL-1 for Magnesium**



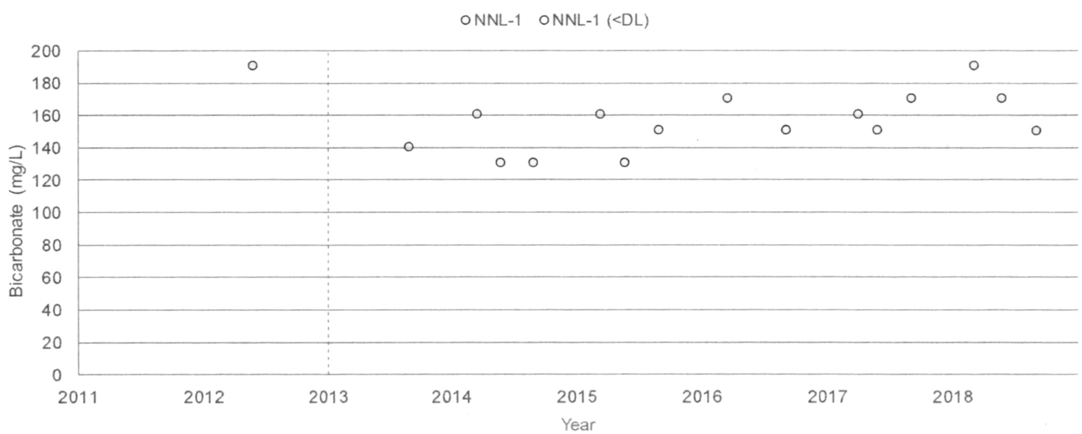
DL = detection limit; < = less than.

Figure VII-99 **Time Series Plot at Station NNL-1 for Potassium**



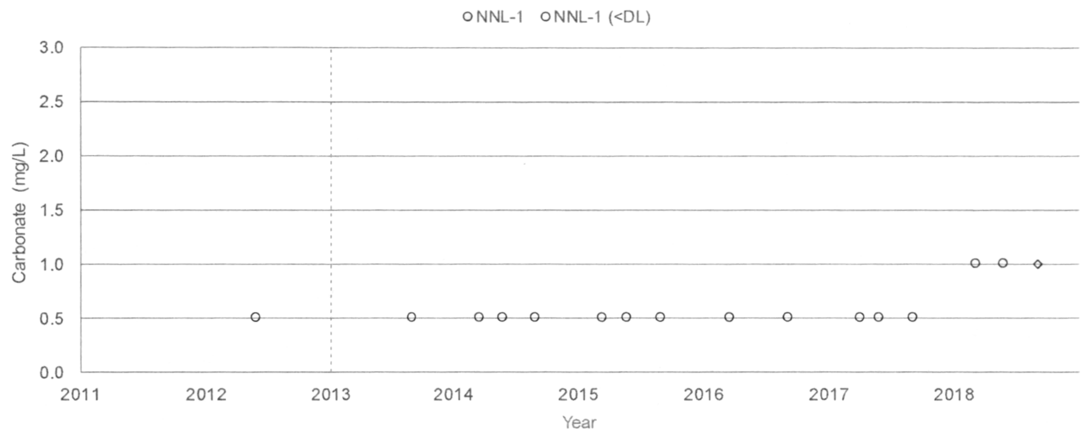
DL = detection limit; < = less than.

Figure VII-100 Time Series Plot at Station NNL-1 for Sodium



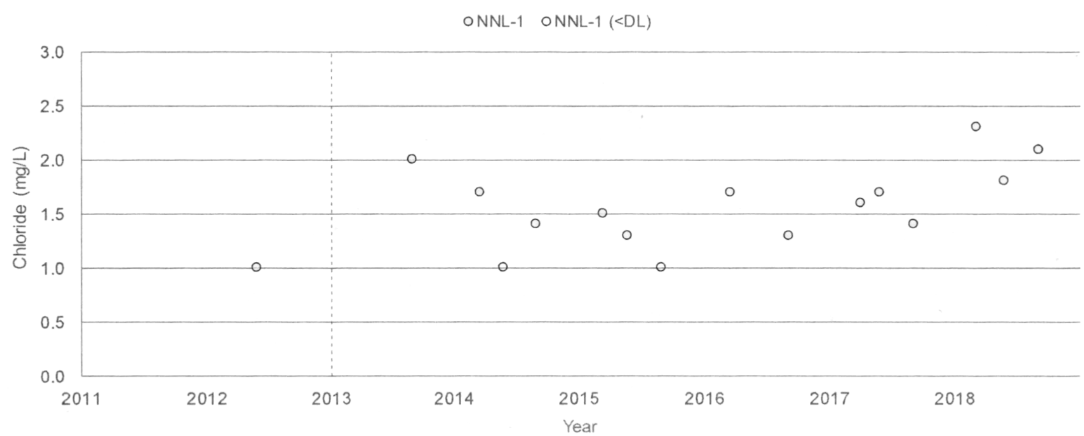
DL = detection limit; < = less than.

Figure VII-101 Time Series Plot at Station NNL-1 for Bicarbonate



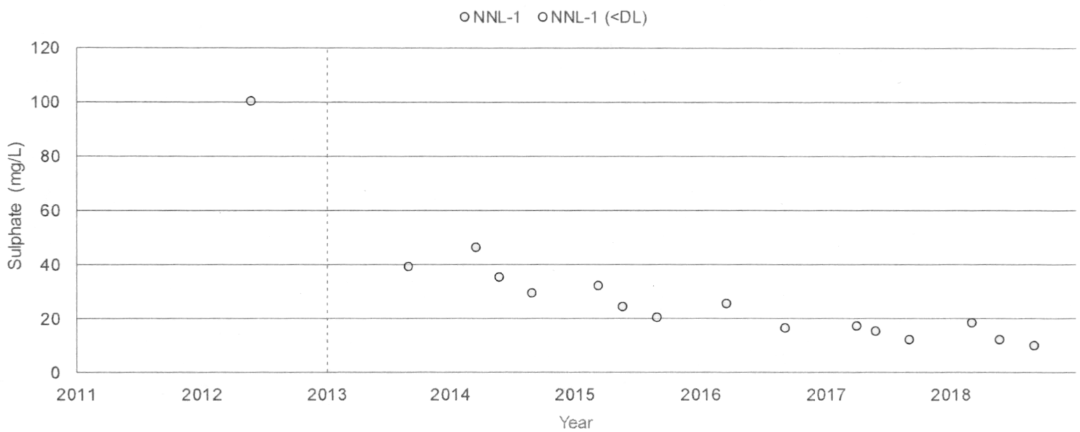
DL = detection limit; < = less than.

Figure VII-102 **Time Series Plot at Station NNL-1 for Carbonate**



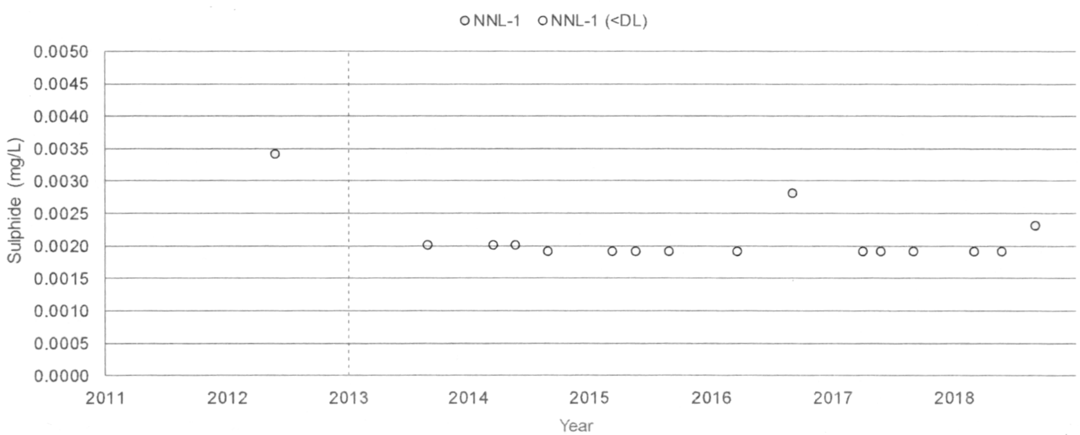
DL = detection limit; < = less than.

Figure VII-103 **Time Series Plot at Station NNL-1 for Chloride**



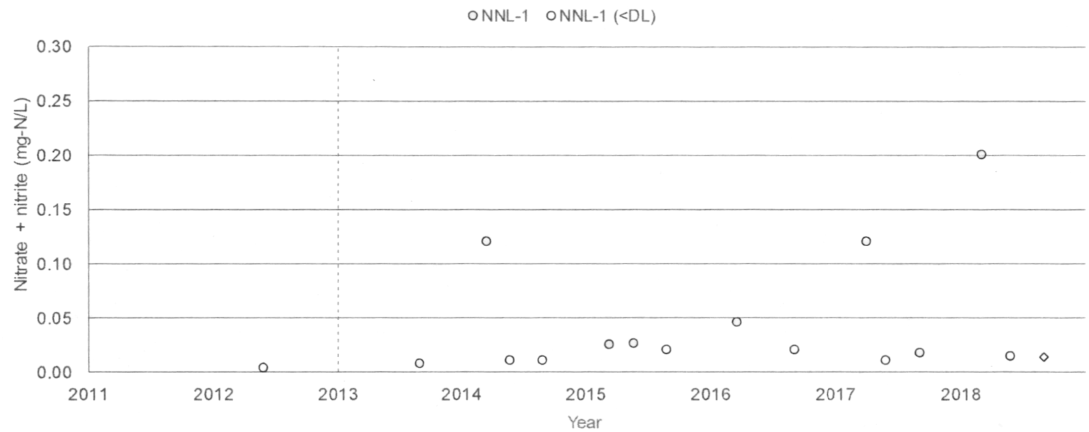
DL = detection limit; < = less than.

Figure VII-104 **Time Series Plot at Station NNL-1 for Sulphate**



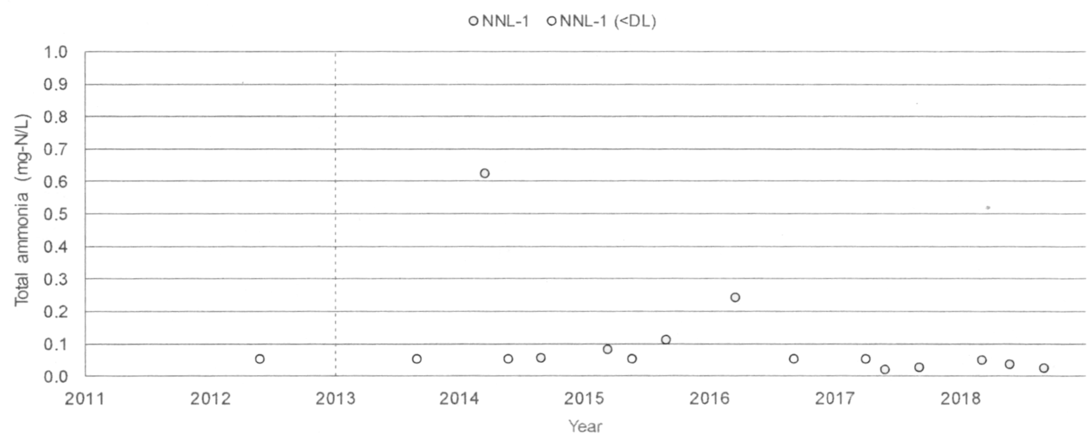
DL = detection limit; < = less than.

Figure VII-105 **Time Series Plot at Station NNL-1 for Sulphide**



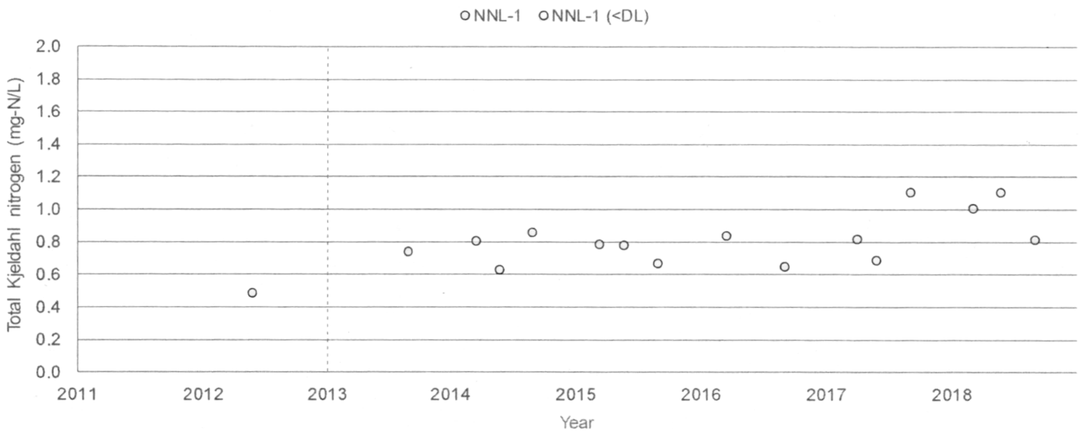
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-106 Time Series Plot at Station NNL-1 for Nitrate + Nitrite



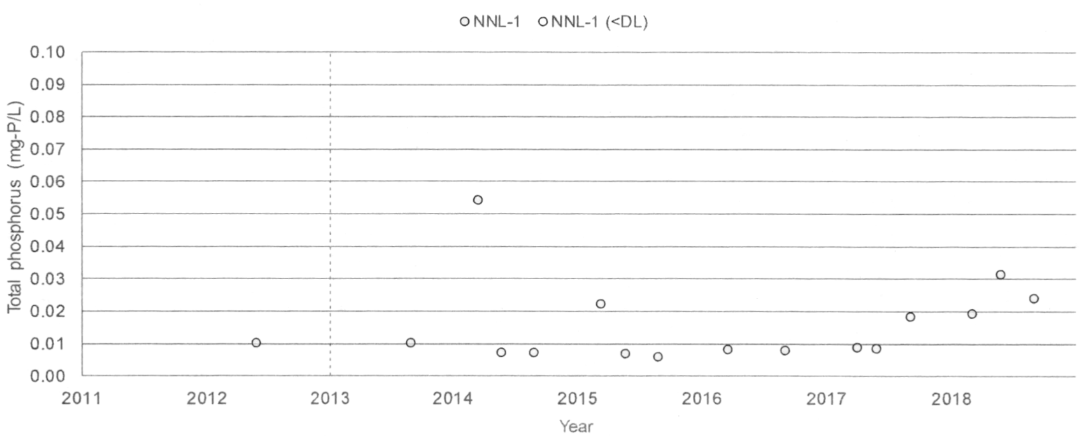
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-107 Time Series Plot at Station NNL-1 for Total Ammonia



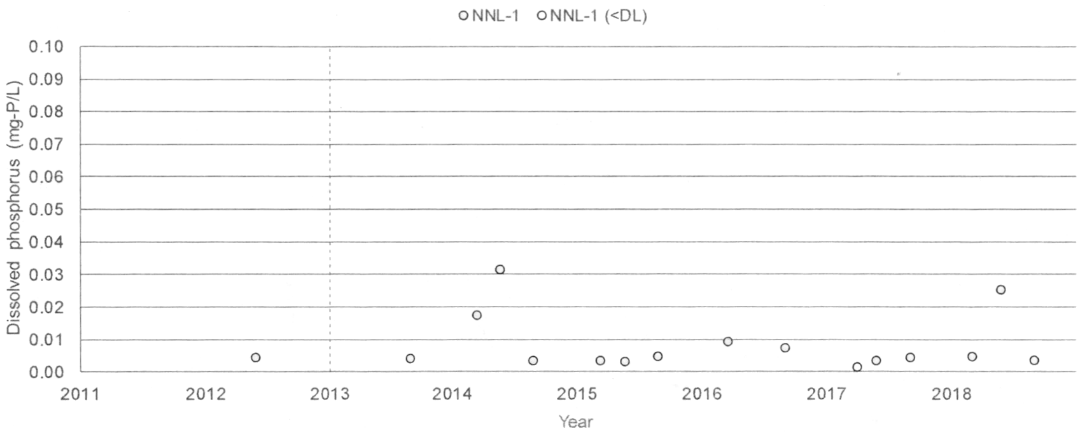
mg-N/L = milligrams as nitrogen per litre; DL = detection limit; < = less than.

Figure VII-108 **Time Series Plot at Station NNL-1 for Total Kjeldahl Nitrogen**



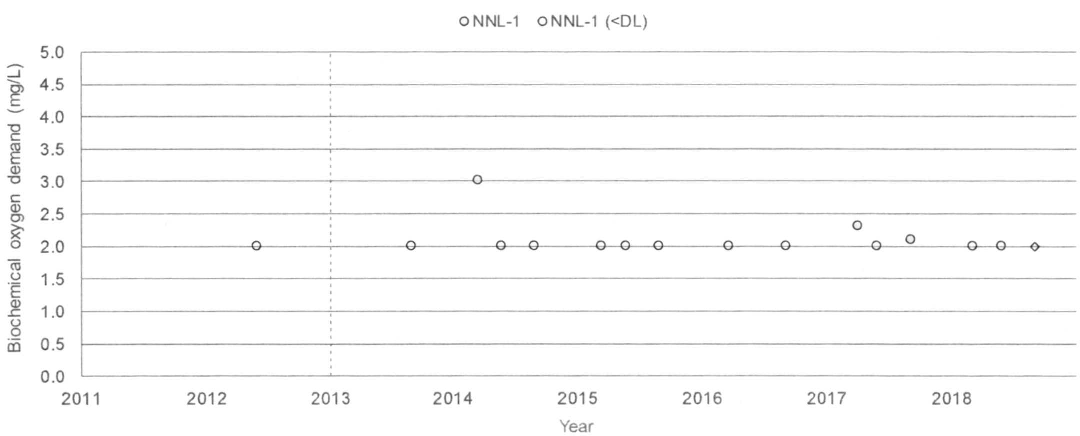
mg-P/L = milligrams as phosphorus per litre; DL = detection limit; < = less than.

Figure VII-109 **Time Series Plot at Station NNL-1 for Total Phosphorus**



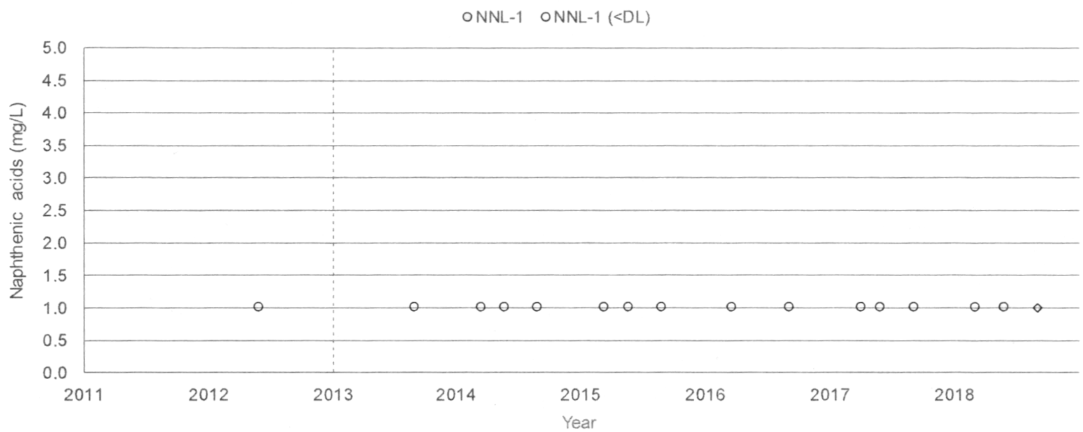
mg-P/L = milligrams as phosphorus per litre; DL = detection limit; < = less than.

Figure VII-110 **Time Series Plot at Station NNL-1 for Dissolved Phosphorus**



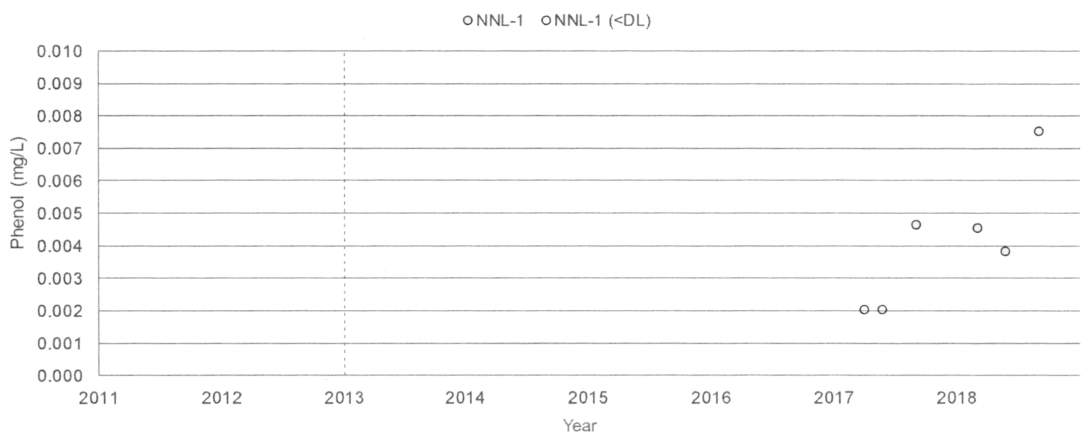
DL = detection limit; < = less than.

Figure VII-111 **Time Series Plot at Station NNL-1 for Biochemical Oxygen Demand**



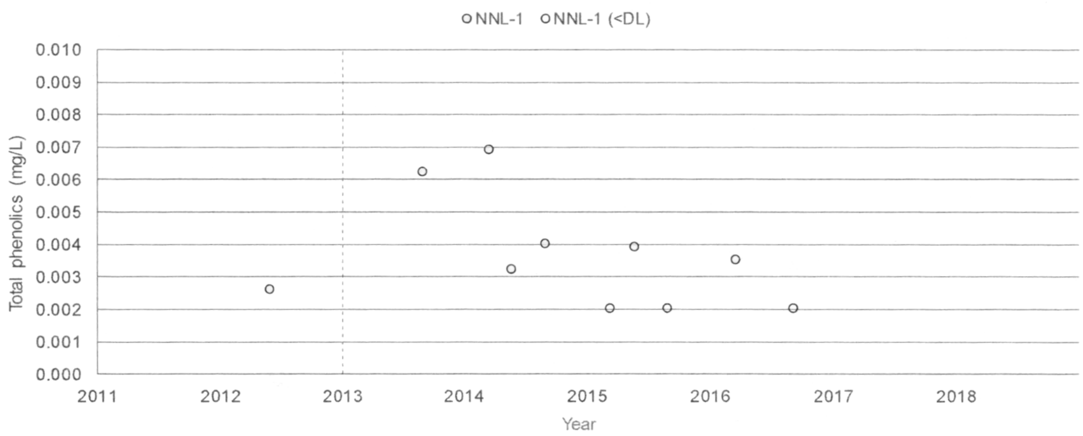
DL = detection limit; < = less than.

Figure VII-112 **Time Series Plot at Station NNL-1 for Naphthenic Acids**



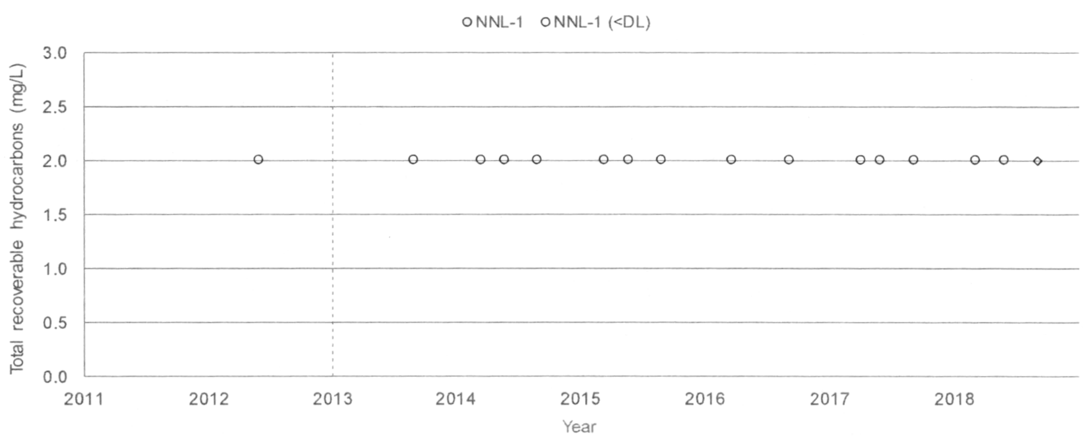
DL = detection limit; < = less than.

Figure VII-113 **Time Series Plot at Station NNL-1 for Phenol**



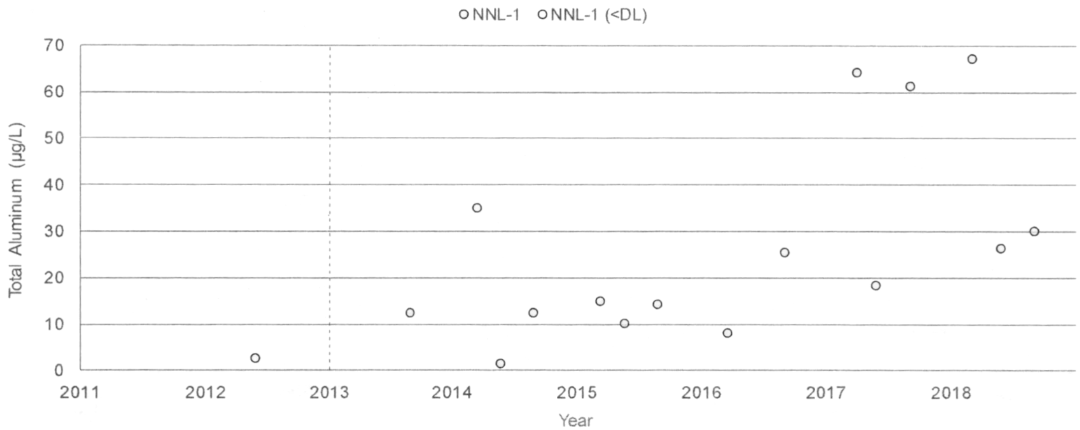
DL = detection limit; < = less than.

Figure VII-114 Time Series Plot at Station NNL-1 for Total Phenolics



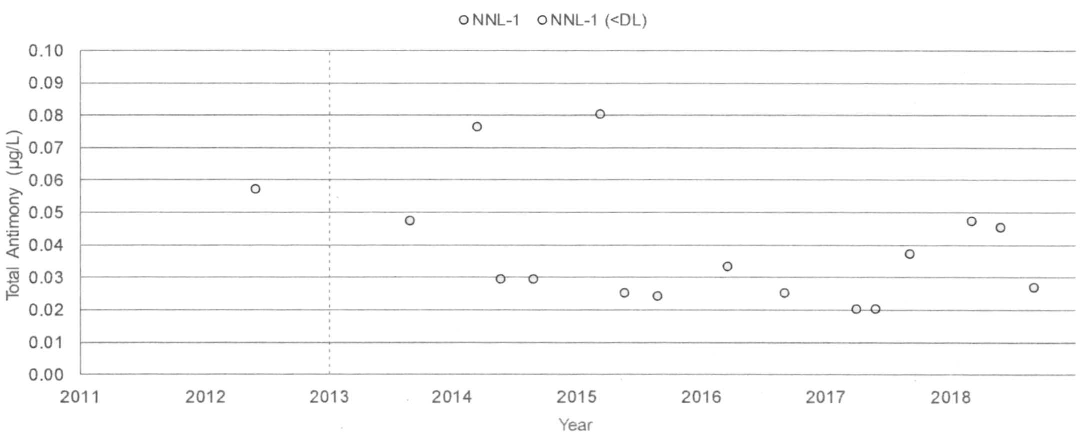
DL = detection limit; < = less than.

Figure VII-115 Time Series Plot at Station NNL-1 for Total Recoverable Hydrocarbons



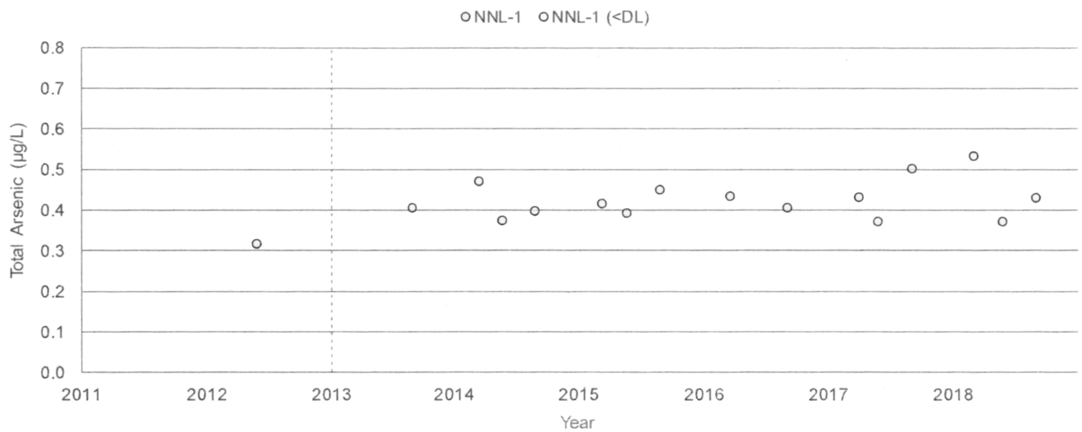
DL = detection limit; < = less than.

Figure VII-116 **Time Series Plot at Station NNL-1 for Total Aluminum**



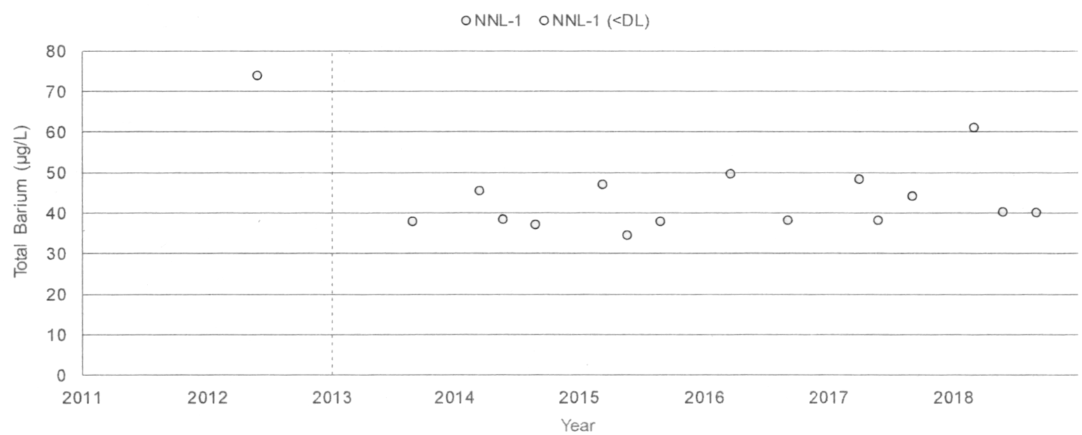
DL = detection limit; < = less than.

Figure VII-117 **Time Series Plot at Station NNL-1 for Total Antimony**



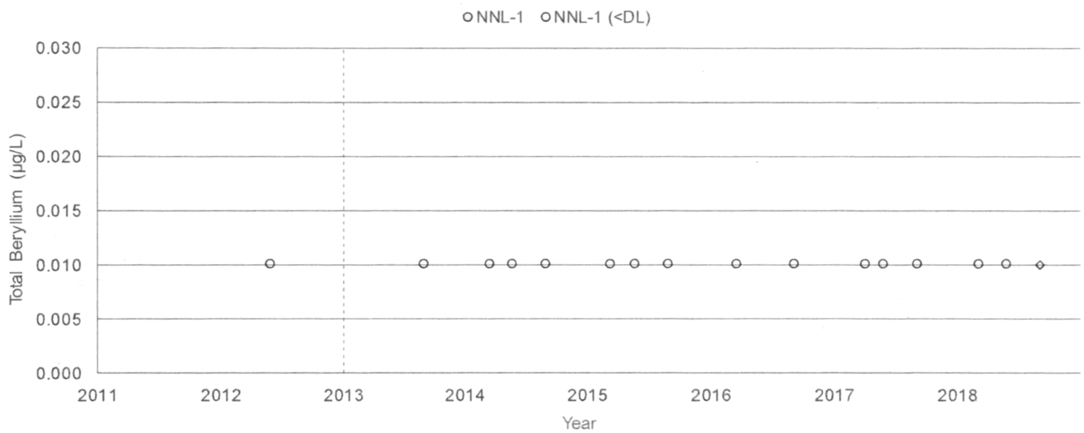
DL = detection limit; < = less than.

Figure VII-118 Time Series Plot at Station NNL-1 for Total Arsenic



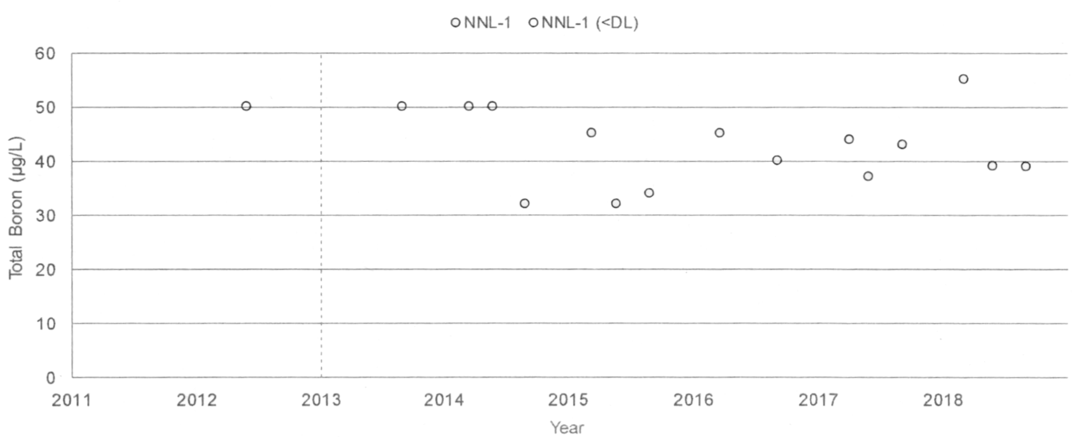
DL = detection limit; < = less than.

Figure VII-119 Time Series Plot at Station NNL-1 for Total Barium



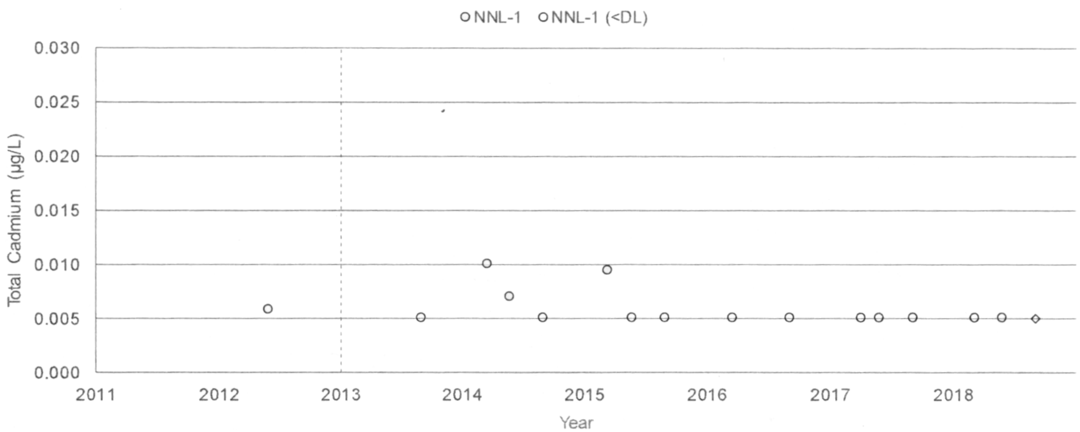
DL = detection limit; < = less than.

Figure VII-120 **Time Series Plot at Station NNL-1 for Total Beryllium**



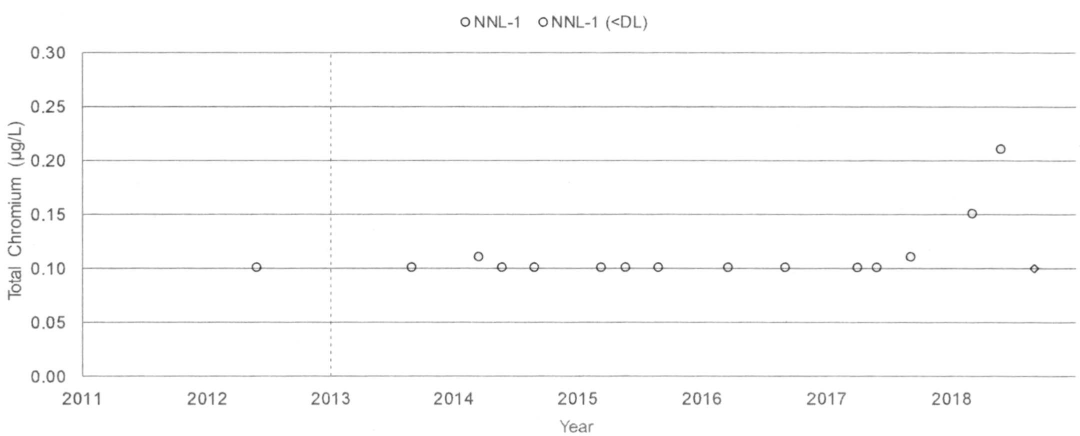
DL = detection limit; < = less than.

Figure VII-121 **Time Series Plot at Station NNL-1 for Total Boron**



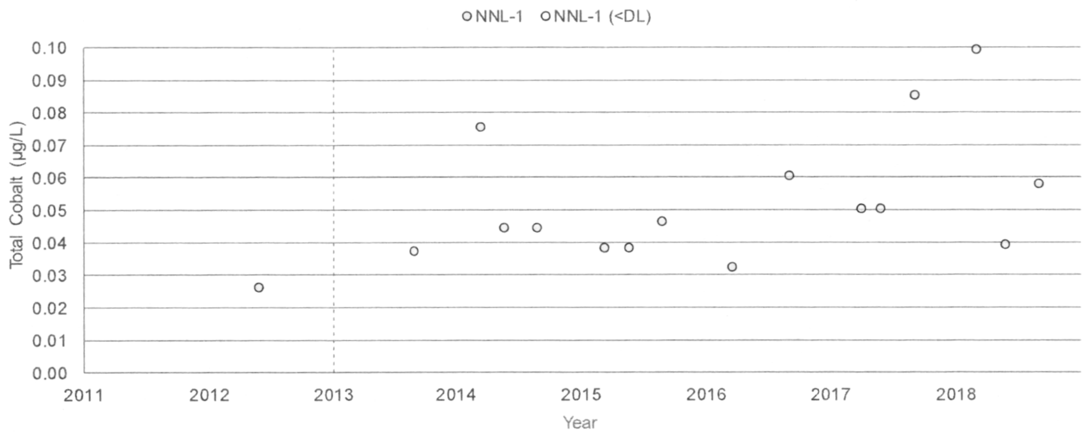
DL = detection limit; < = less than.

Figure VII-122 **Time Series Plot at Station NNL-1 for Total Cadmium**



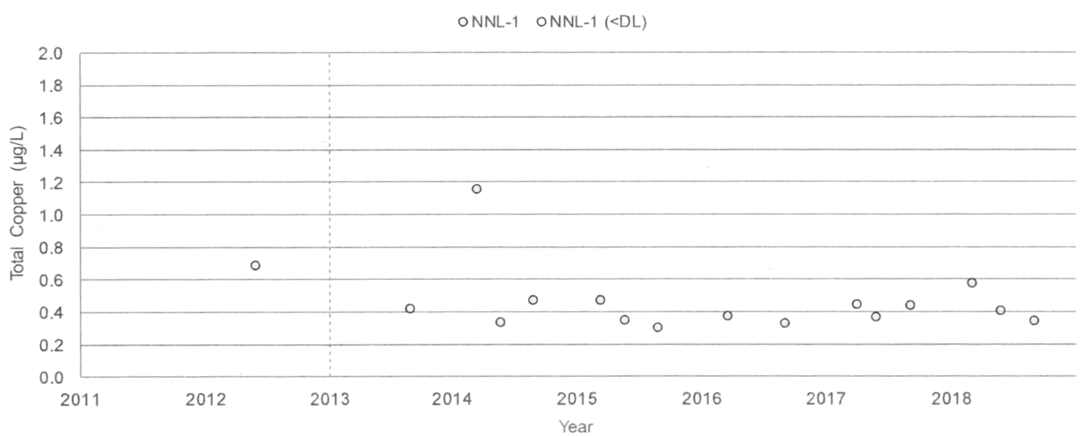
DL = detection limit; < = less than.

Figure VII-123 **Time Series Plot at Station NNL-1 for Total Chromium**



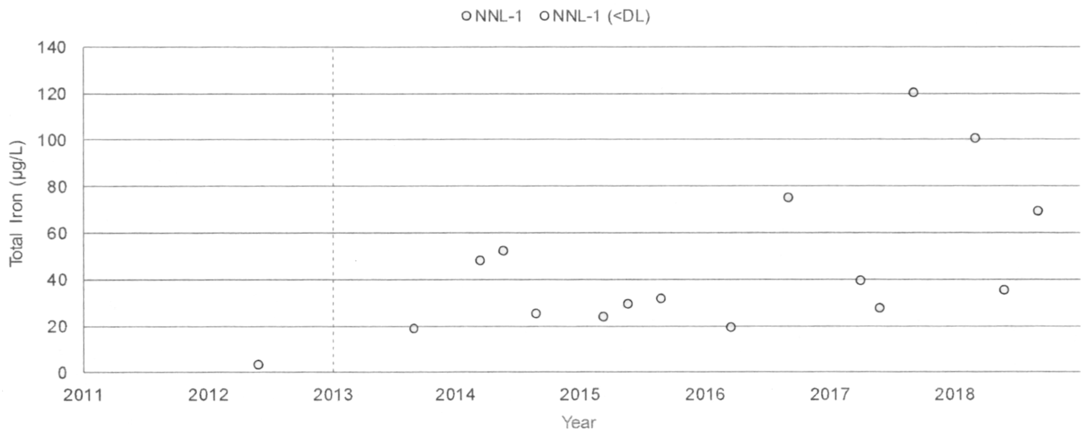
DL = detection limit; < = less than.

Figure VII-124 **Time Series Plot at Station NNL-1 for Total Cobalt**



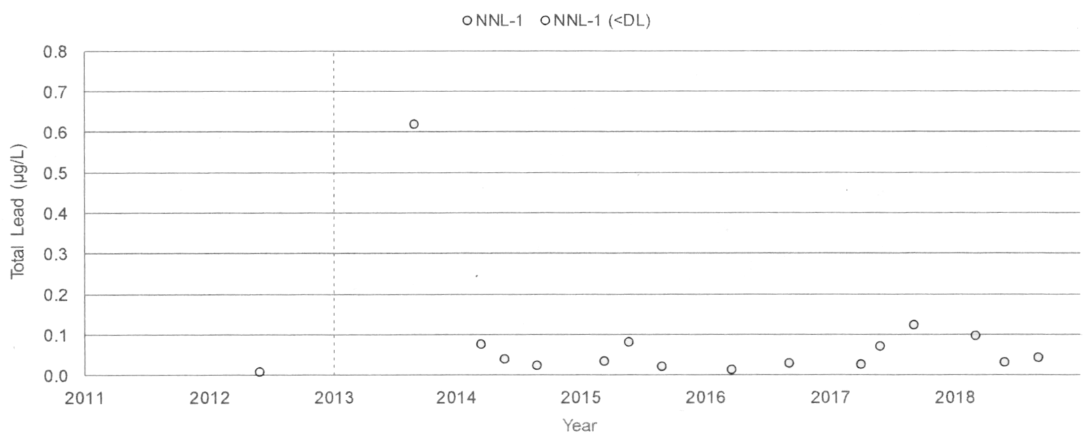
DL = detection limit; < = less than.

Figure VII-125 **Time Series Plot at Station NNL-1 for Total Copper**



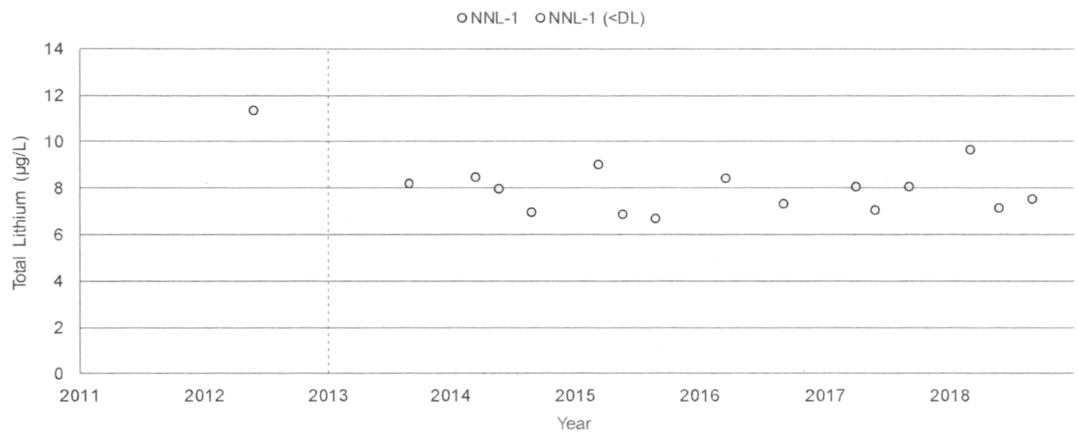
DL = detection limit; < = less than.

Figure VII-126 **Time Series Plot at Station NNL-1 for Total Iron**



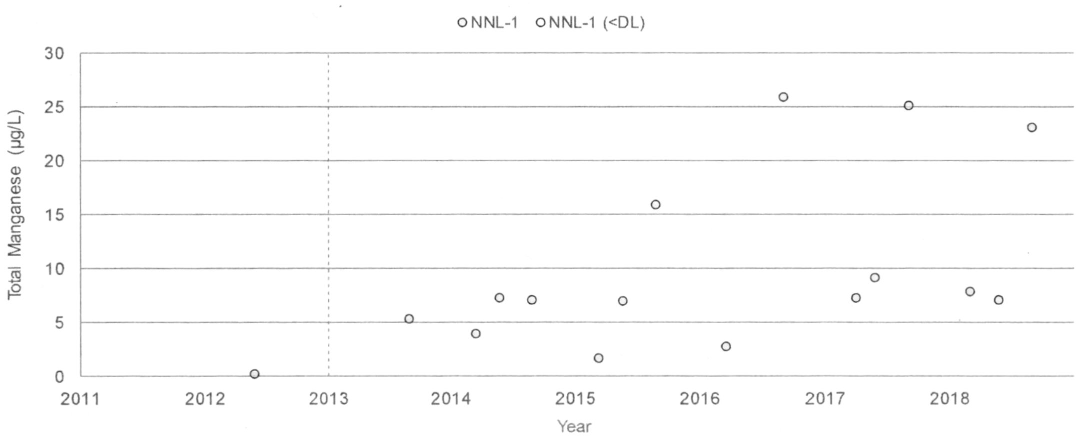
DL = detection limit; < = less than.

Figure VII-127 **Time Series Plot at Station NNL-1 for Total Lead**



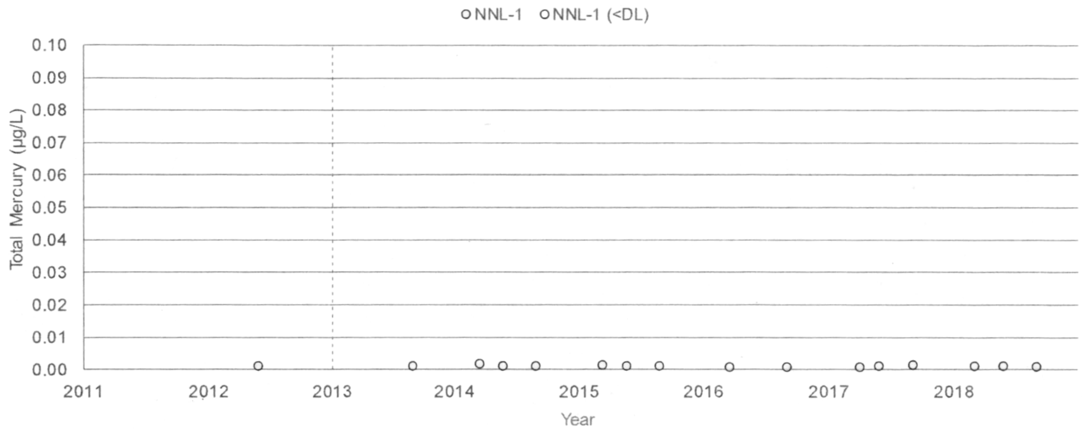
DL = detection limit; < = less than.

Figure VII-128 **Time Series Plot at Station NNL-1 for Total Lithium**



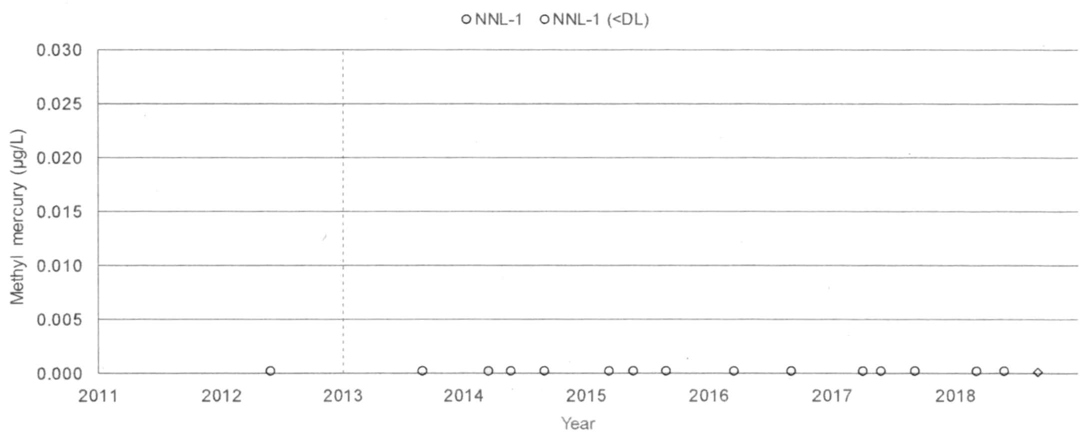
DL = detection limit; < = less than.

Figure VII-129 **Time Series Plot at Station NNL-1 for Total Manganese**



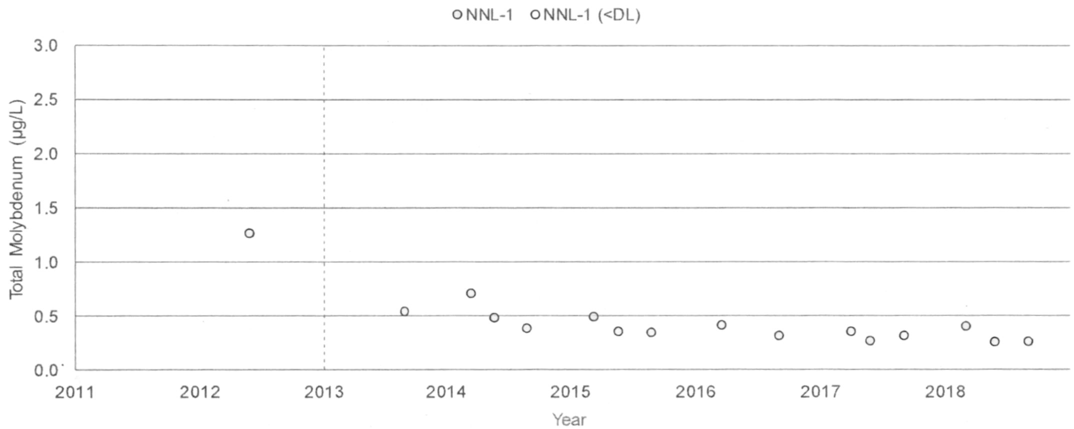
DL = detection limit; < = less than.

Figure VII-130 **Time Series Plot at Station NNL-1 for Total Mercury**



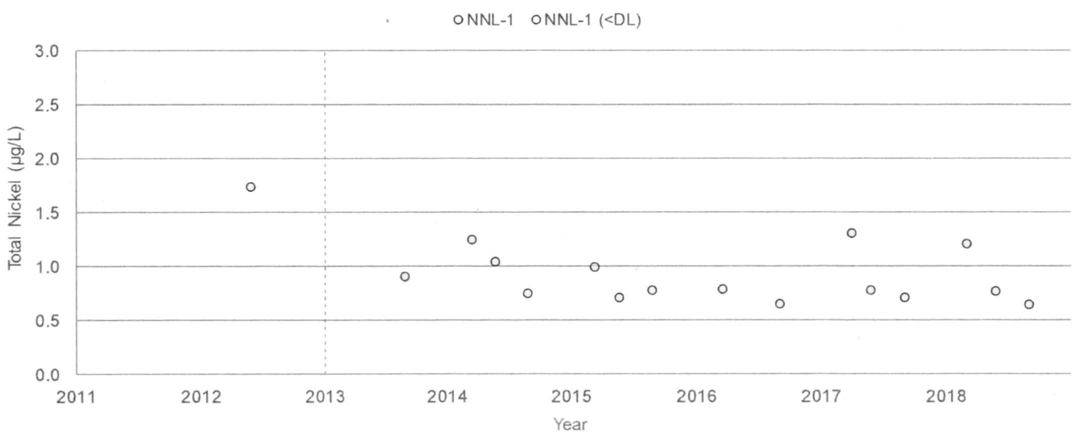
DL = detection limit; < = less than.

Figure VII-131 **Time Series Plot at Station NNL-1 for Methyl Mercury**



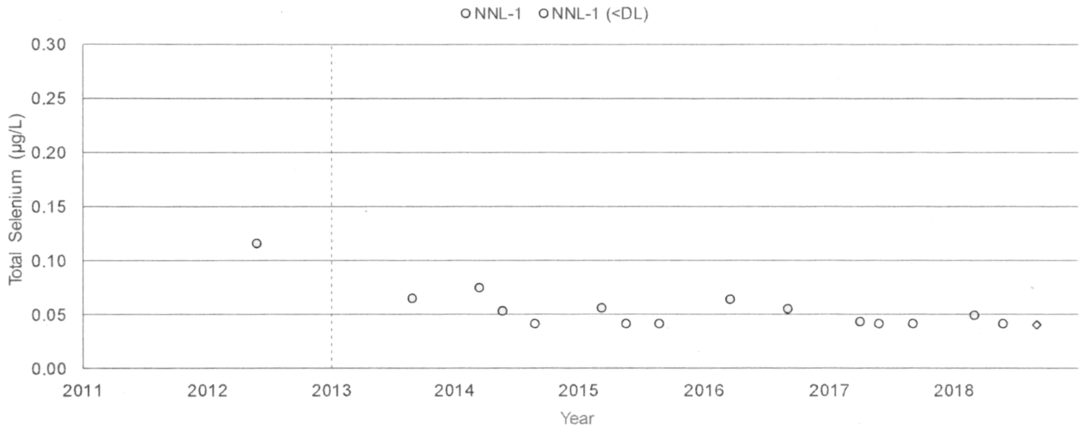
DL = detection limit; < = less than.

Figure VII-132 **Time Series Plot at Station NNL-1 for Total Molybdenum**



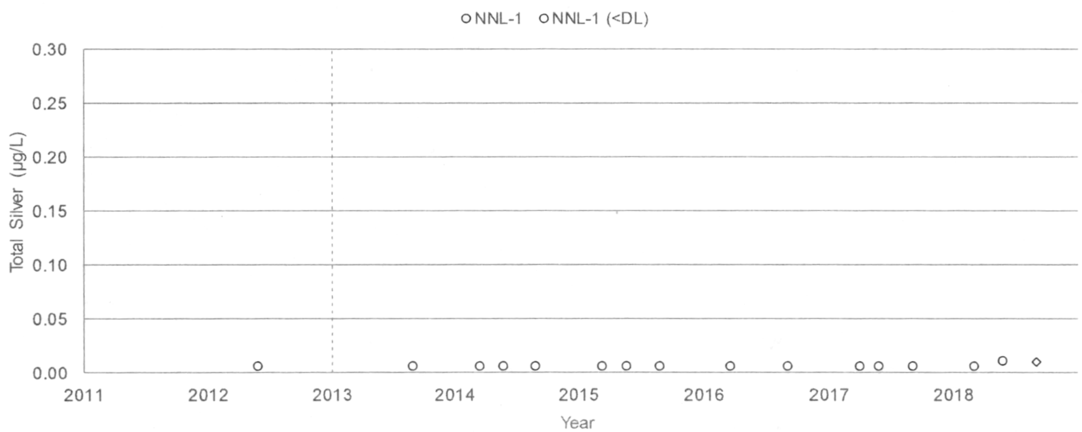
DL = detection limit; < = less than.

Figure VII-133 **Time Series Plot at Station NNL-1 for Total Nickel**



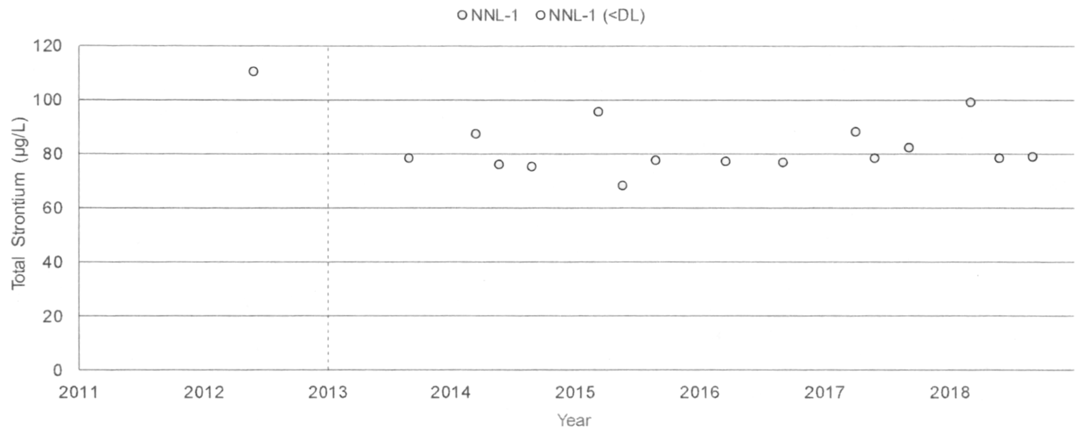
DL = detection limit; < = less than.

Figure VII-134 **Time Series Plot at Station NNL-1 for Total Selenium**



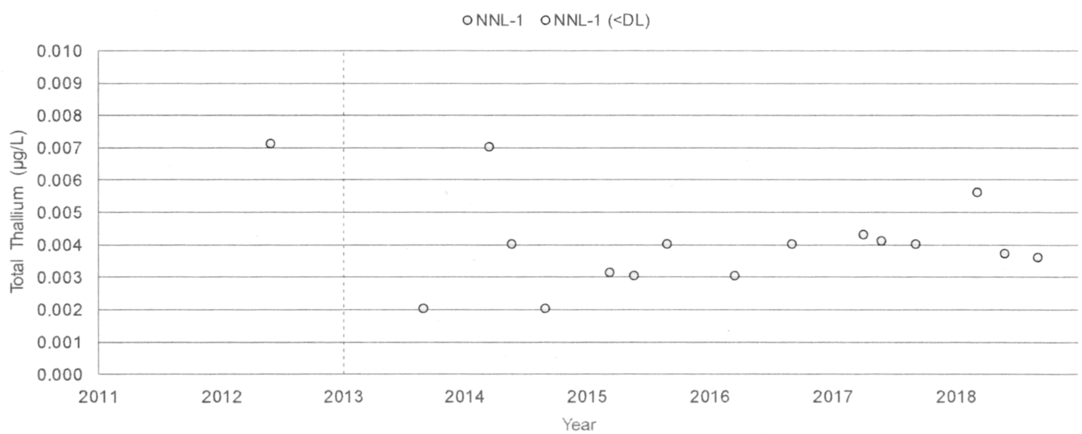
DL = detection limit; < = less than.

Figure VII-135 **Time Series Plot at Station NNL-1 for Total Silver**



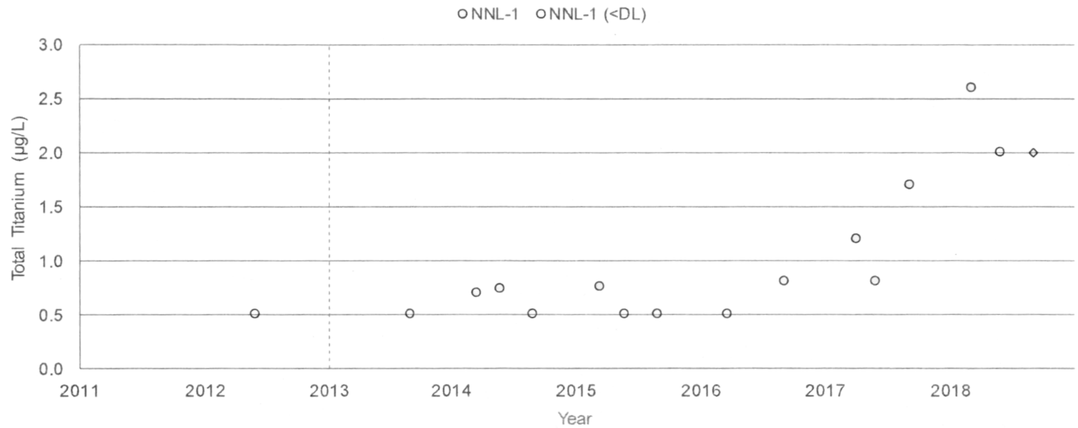
DL = detection limit; < = less than.

Figure VII-136 **Time Series Plot at Station NNL-1 for Total Strontium**



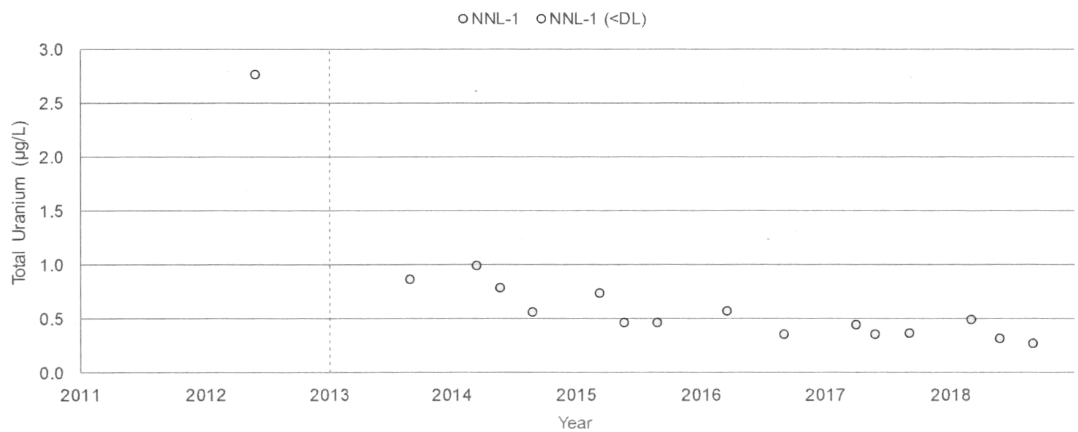
DL = detection limit; < = less than.

Figure VII-137 **Time Series Plot at Station NNL-1 for Total Thallium**



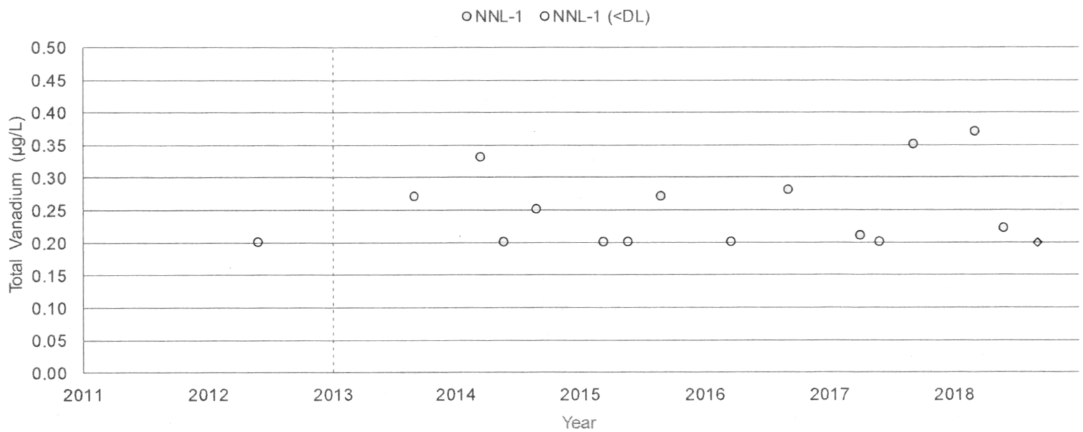
DL = detection limit; < = less than.

Figure VII-138 **Time Series Plot at Station NNL-1 for Total Titanium**



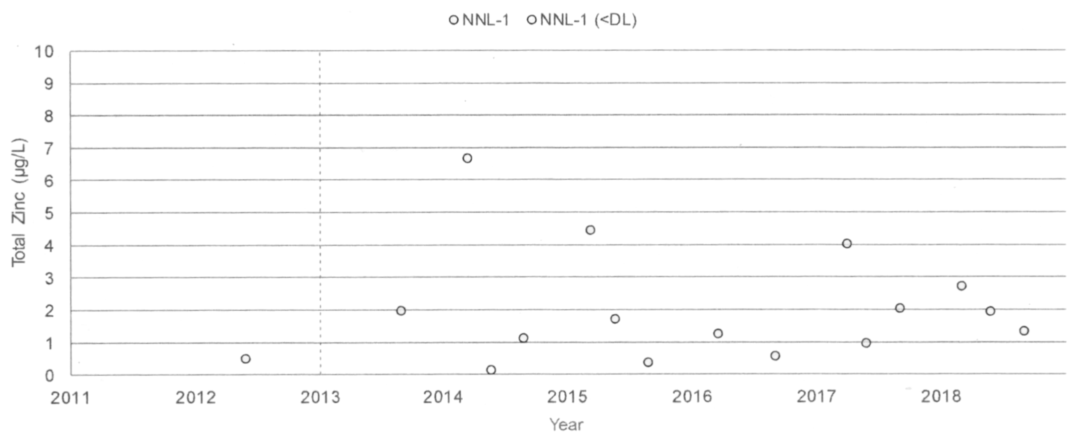
DL = detection limit; < = less than.

Figure VII-139 **Time Series Plot at Station NNL-1 for Total Uranium**



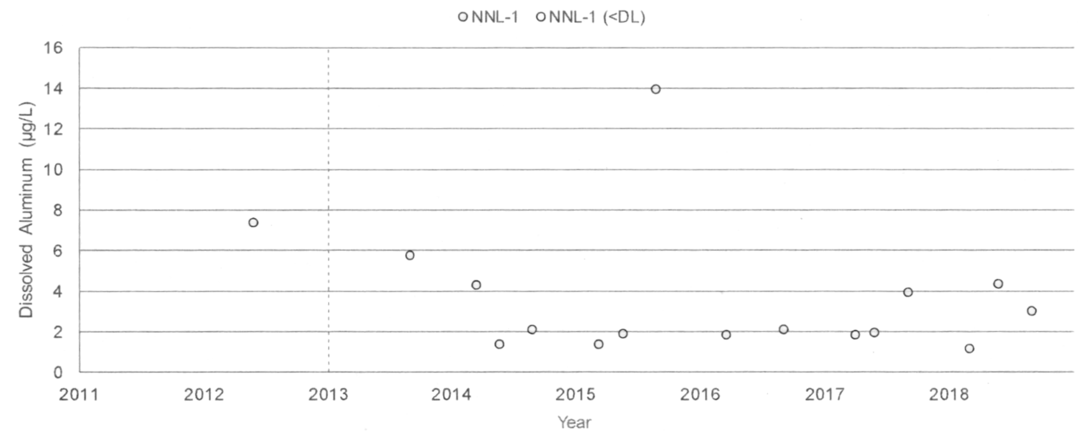
DL = detection limit; < = less than.

Figure VII-140 **Time Series Plot at Station NNL-1 for Total Vanadium**



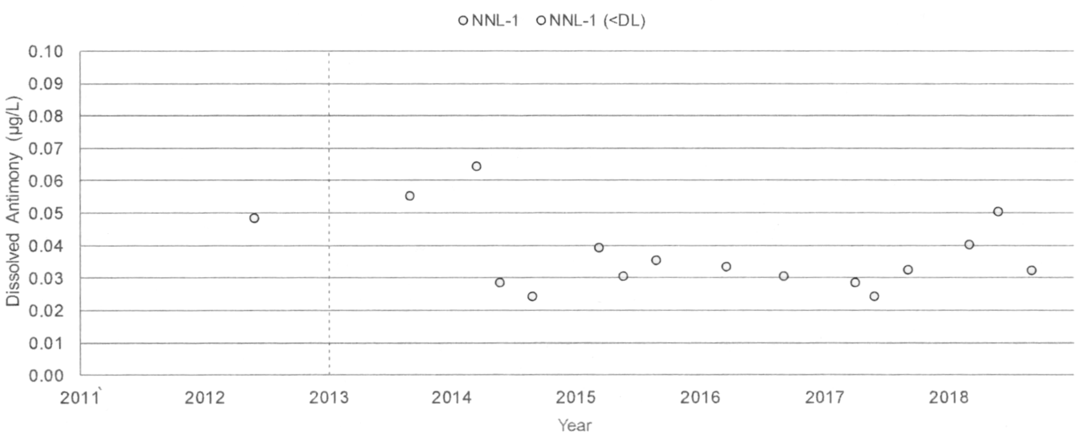
DL = detection limit; < = less than.

Figure VII-141 **Time Series Plot at Station NNL-1 for Total Zinc**



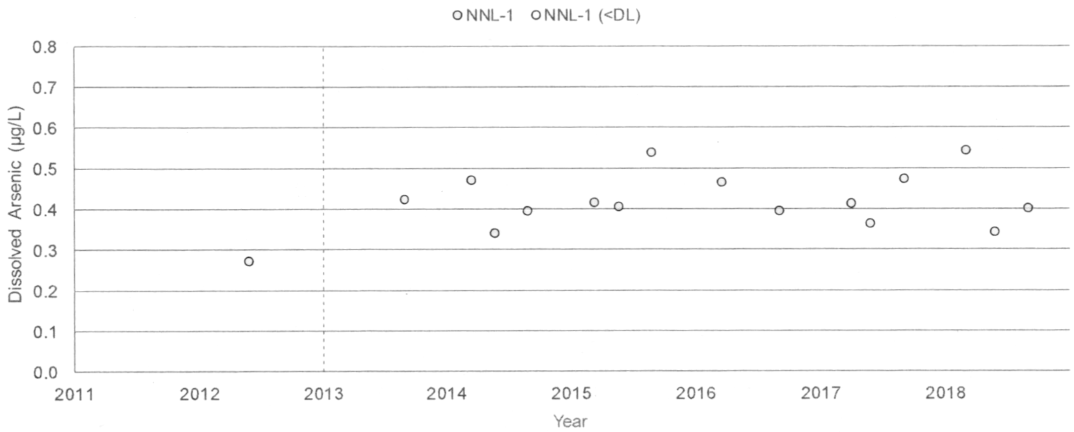
DL = detection limit; < = less than.

Figure VII-142 **Time Series Plot at Station NNL-1 for Dissolved Aluminum**



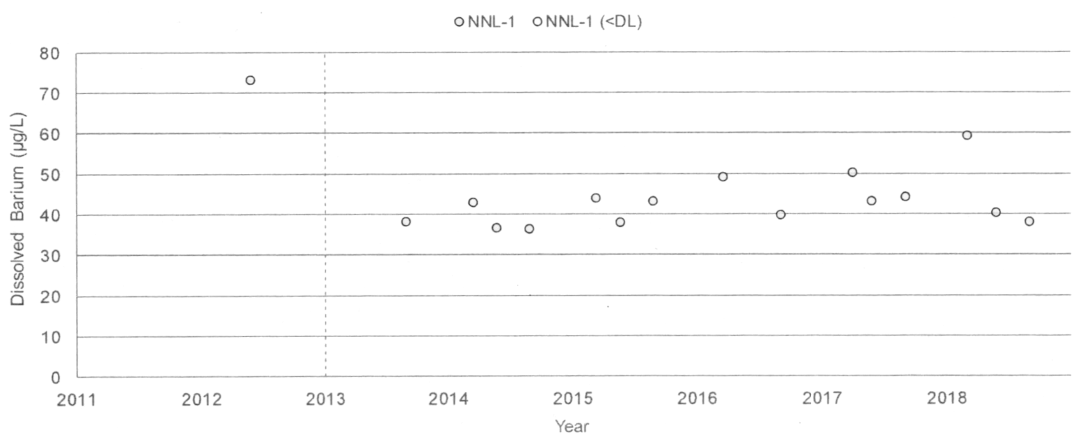
DL = detection limit; < = less than.

Figure VII-143 **Time Series Plot at Station NNL-1 for Dissolved Antimony**



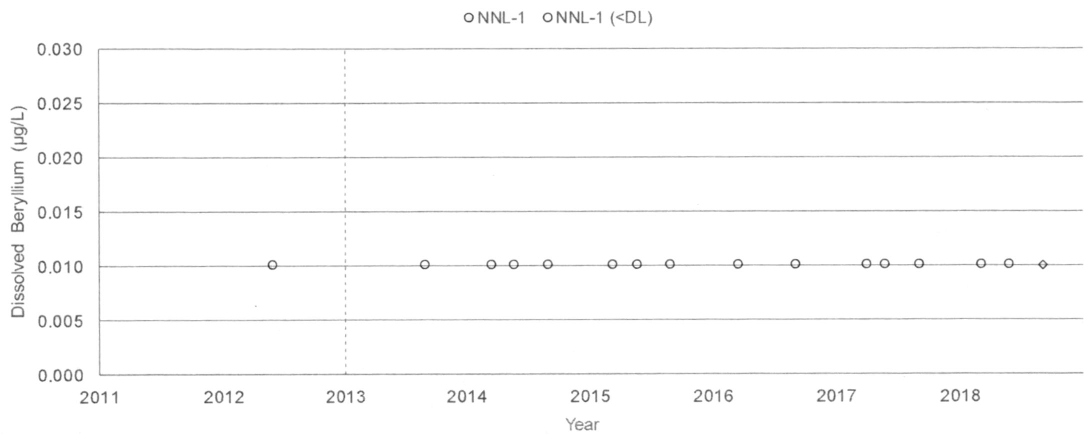
DL = detection limit; < = less than.

Figure VII-144 **Time Series Plot at Station NNL-1 for Dissolved Arsenic**



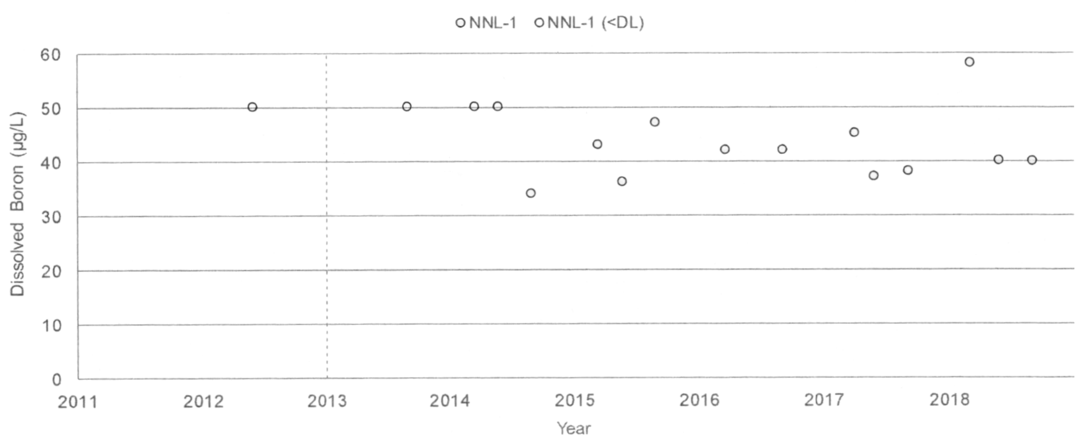
DL = detection limit; < = less than.

Figure VII-145 **Time Series Plot at Station NNL-1 for Dissolved Barium**



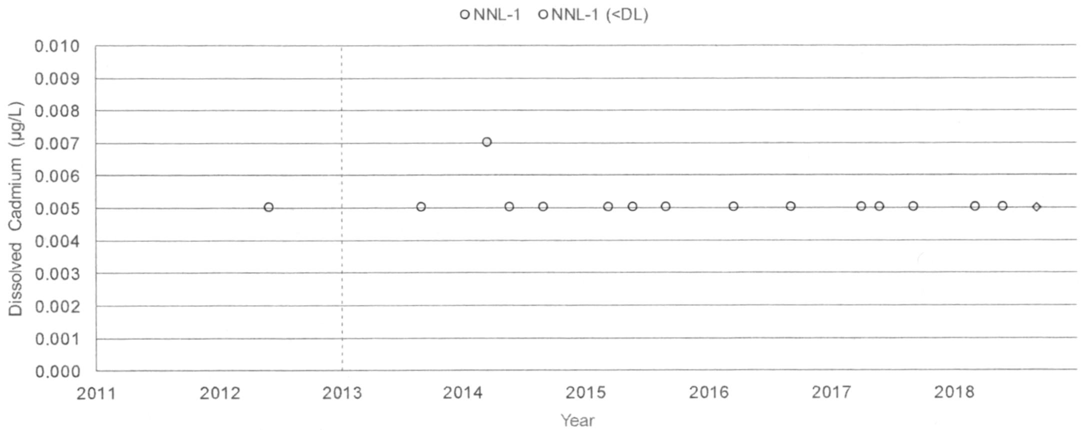
DL = detection limit; < = less than.

Figure VII-146 **Time Series Plot at Station NNL-1 for Dissolved Beryllium**



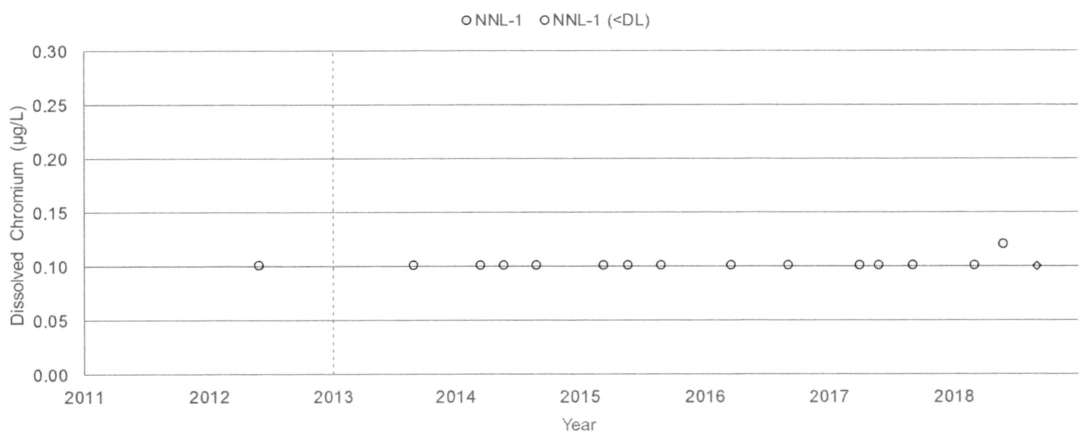
DL = detection limit; < = less than.

Figure VII-147 **Time Series Plot at Station NNL-1 for Dissolved Boron**



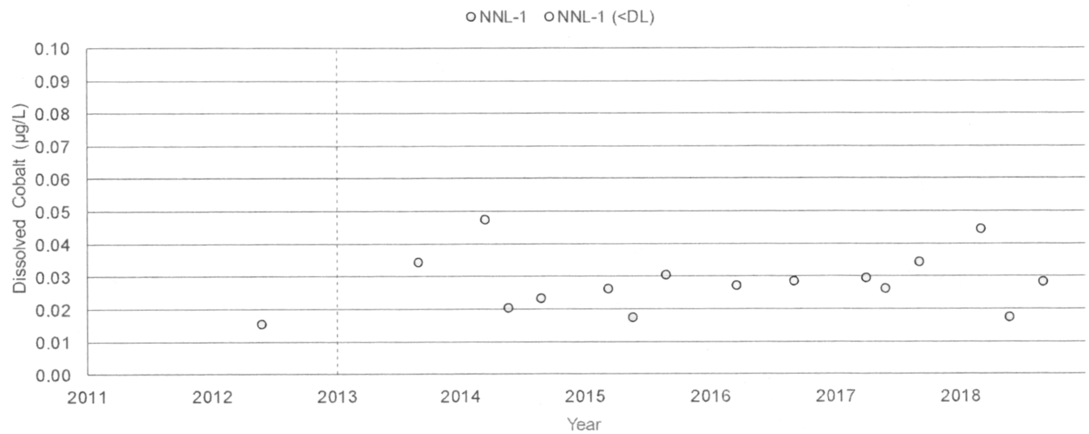
DL = detection limit; < = less than.

Figure VII-148 **Time Series Plot at Station NNL-1 for Dissolved Cadmium**



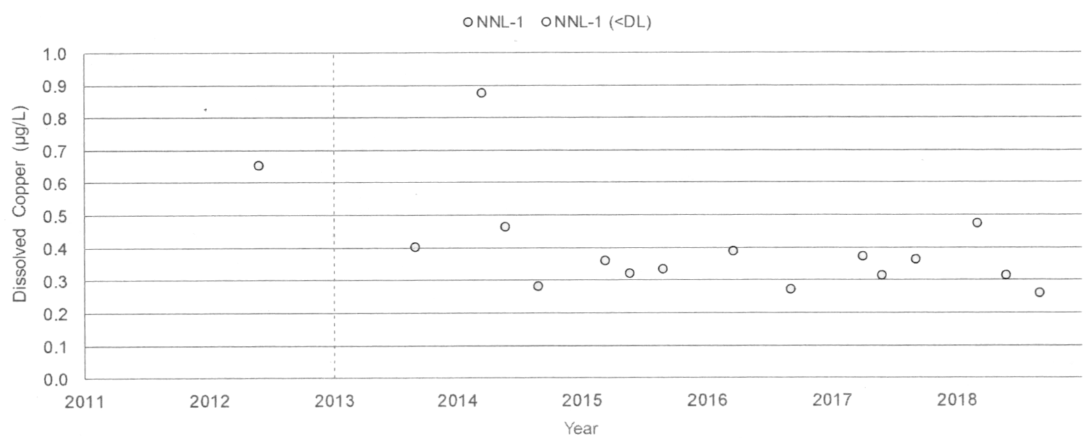
DL = detection limit; < = less than.

Figure VII-149 **Time Series Plot at Station NNL-1 for Dissolved Chromium**



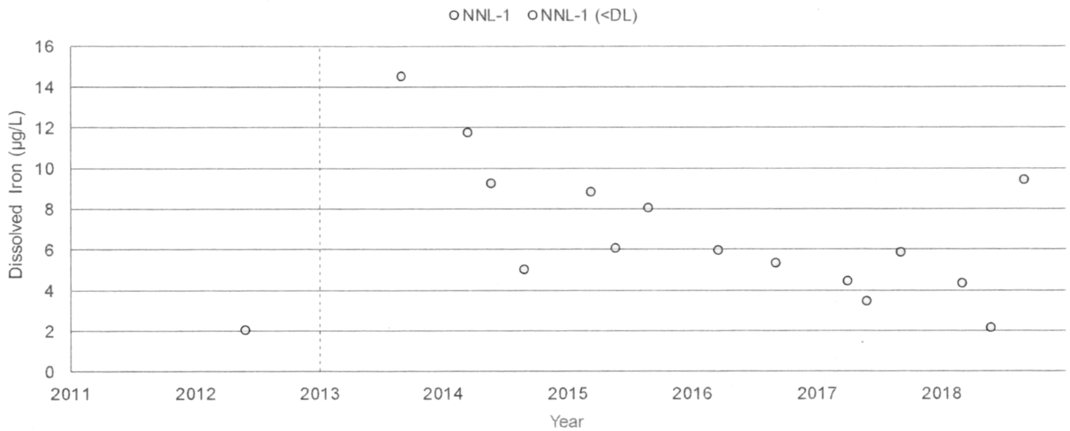
DL = detection limit; < = less than.

Figure VII-150 **Time Series Plot at Station NNL-1 for Dissolved Cobalt**



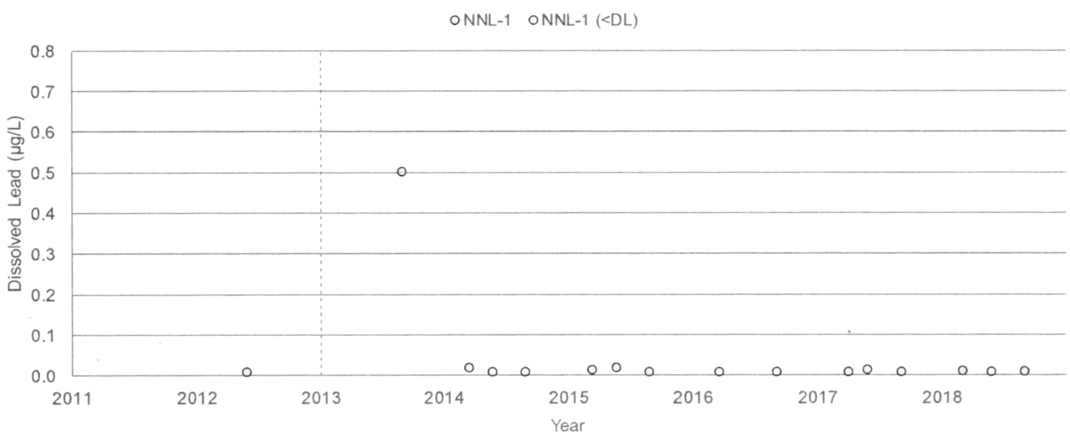
DL = detection limit; < = less than.

Figure VII-151 **Time Series Plot at Station NNL-1 for Dissolved Copper**



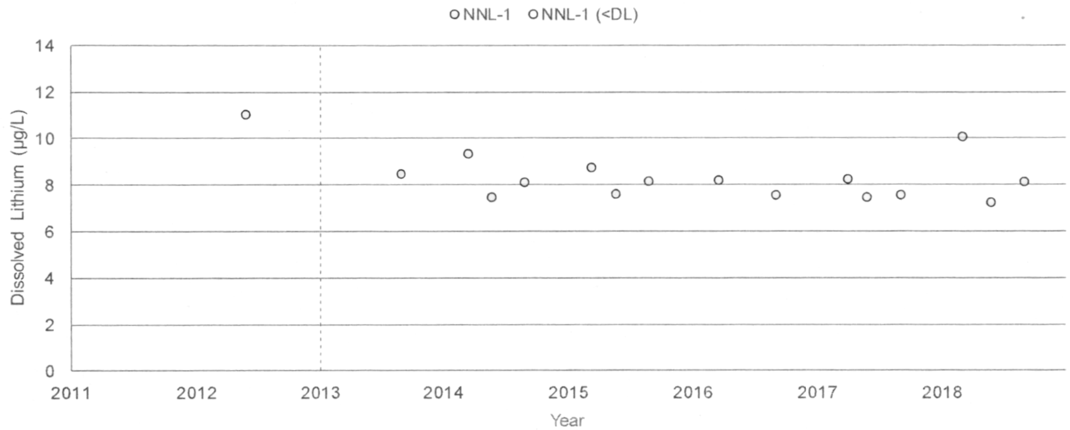
DL = detection limit; < = less than.

Figure VII-152 **Time Series Plot at Station NNL-1 for Dissolved Iron**



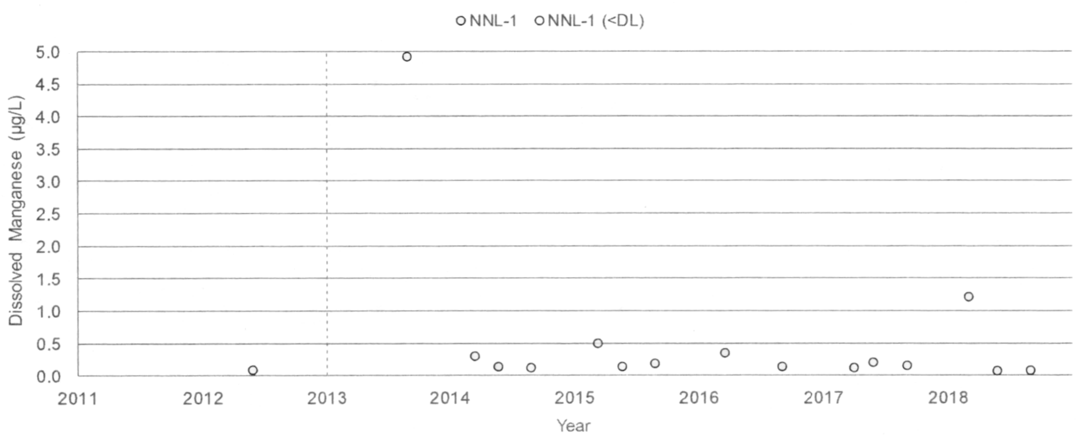
DL = detection limit; < = less than.

Figure VII-153 **Time Series Plot at Station NNL-1 for Dissolved Lead**



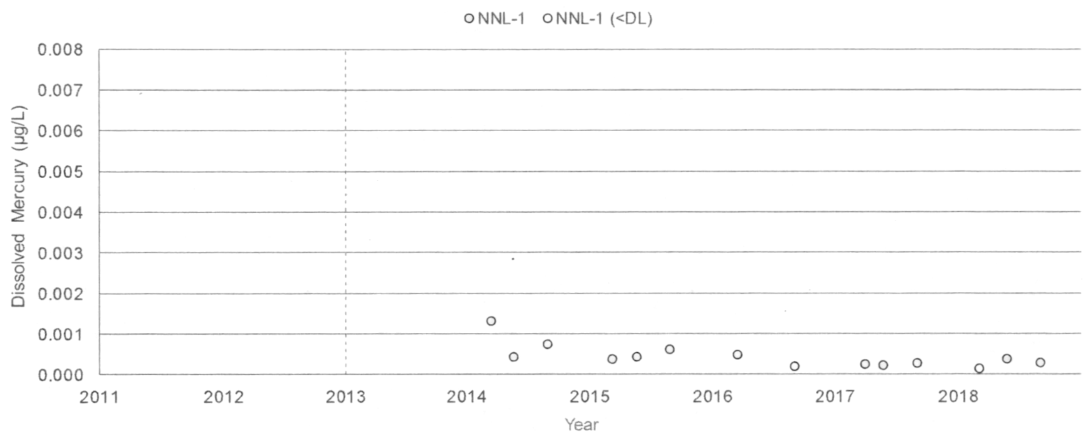
DL = detection limit; < = less than.

Figure VII-154 **Time Series Plot at Station NNL-1 for Dissolved Lithium**



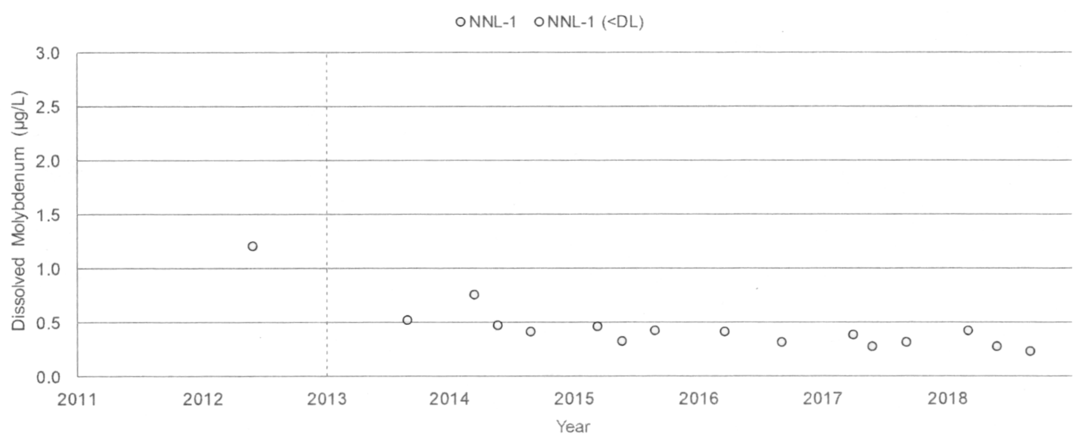
DL = detection limit; < = less than.

Figure VII-155 **Time Series Plot at Station NNL-1 for Dissolved Manganese**



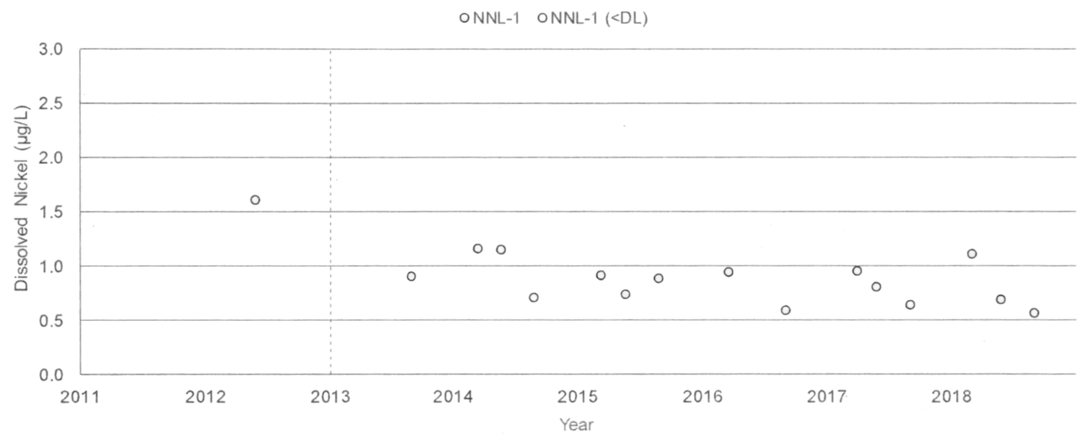
DL = detection limit; < = less than.

Figure VII-156 **Time Series Plot at Station NNL-1 for Dissolved Mercury**



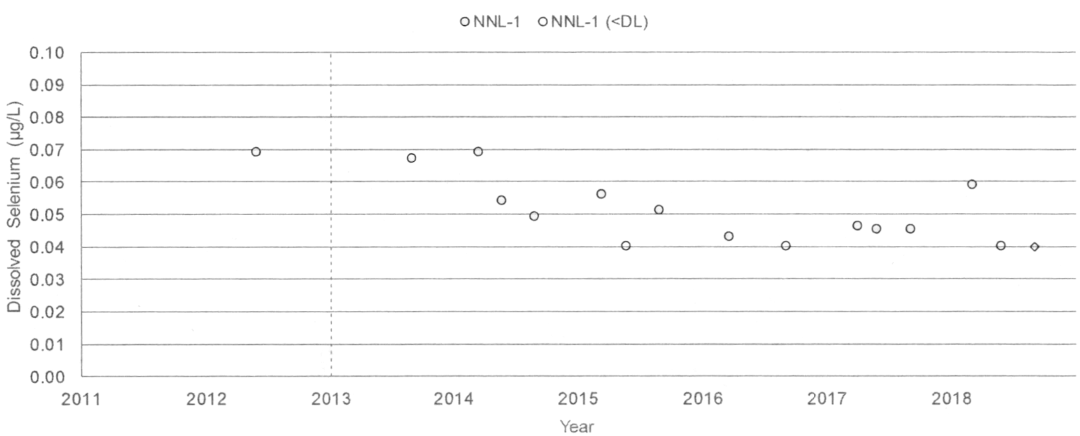
DL = detection limit; < = less than.

Figure VII-157 **Time Series Plot at Station NNL-1 for Dissolved Molybdenum**



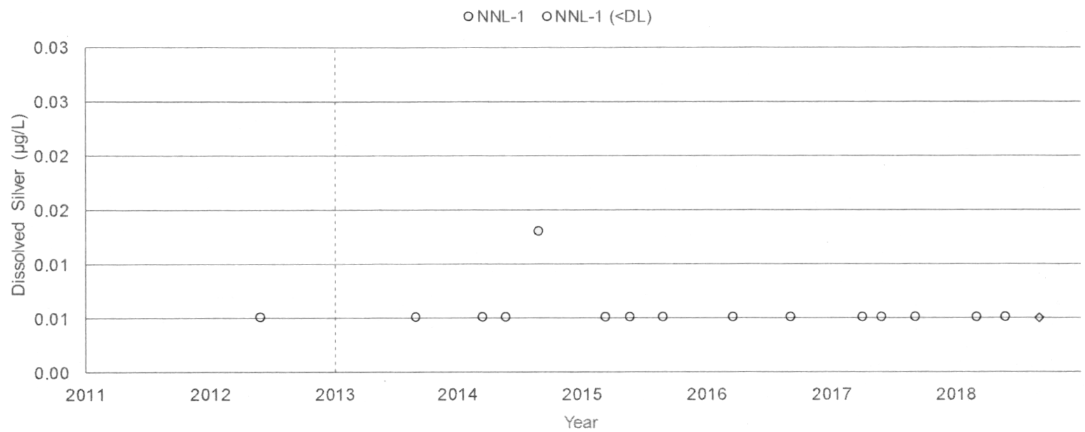
DL = detection limit; < = less than.

Figure VII-158 Time Series Plot at Station NNL-1 for Dissolved Nickel



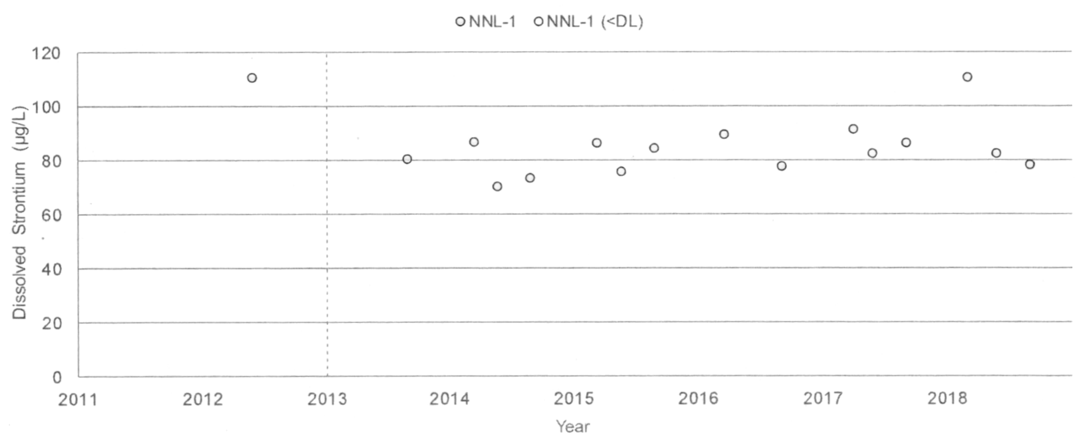
DL = detection limit; < = less than.

Figure VII-159 Time Series Plot at Station NNL-1 for Dissolved Selenium



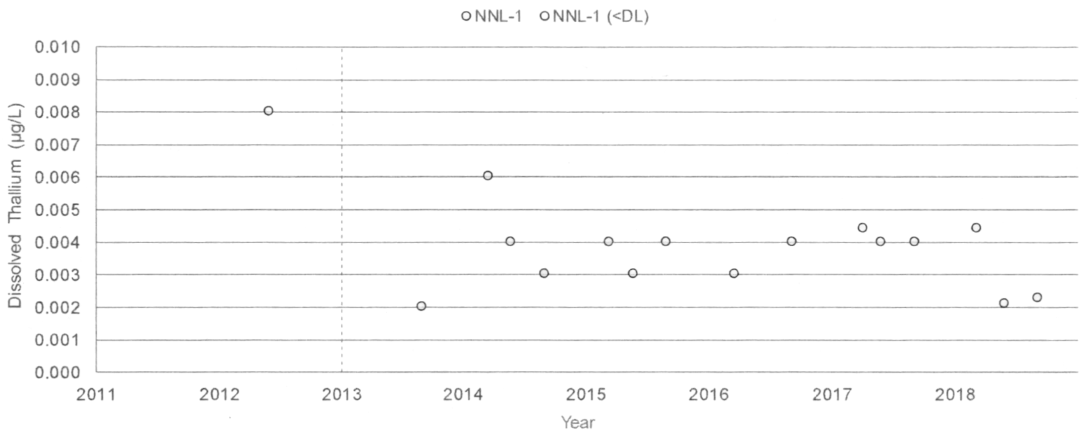
DL = detection limit; < = less than.

Figure VII-160 Time Series Plot at Station NNL-1 for Dissolved Silver



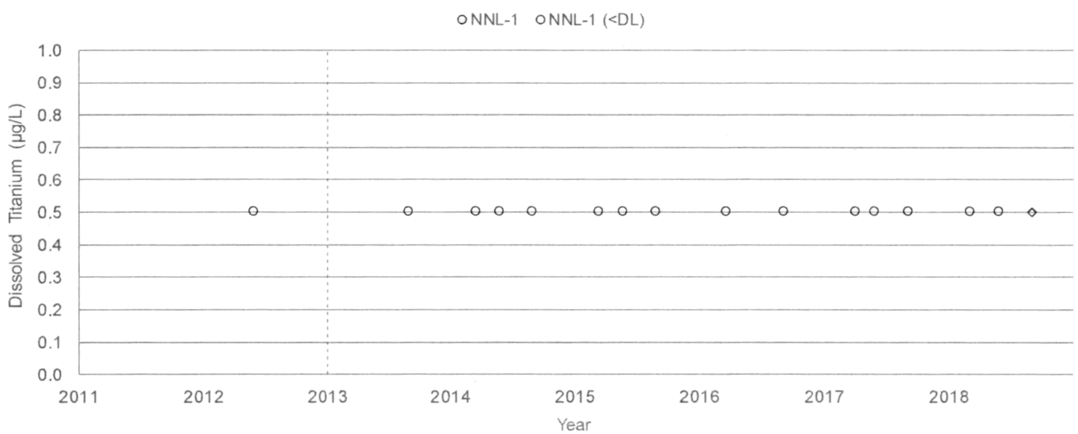
DL = detection limit; < = less than.

Figure VII-161 Time Series Plot at Station NNL-1 for Dissolved Strontium



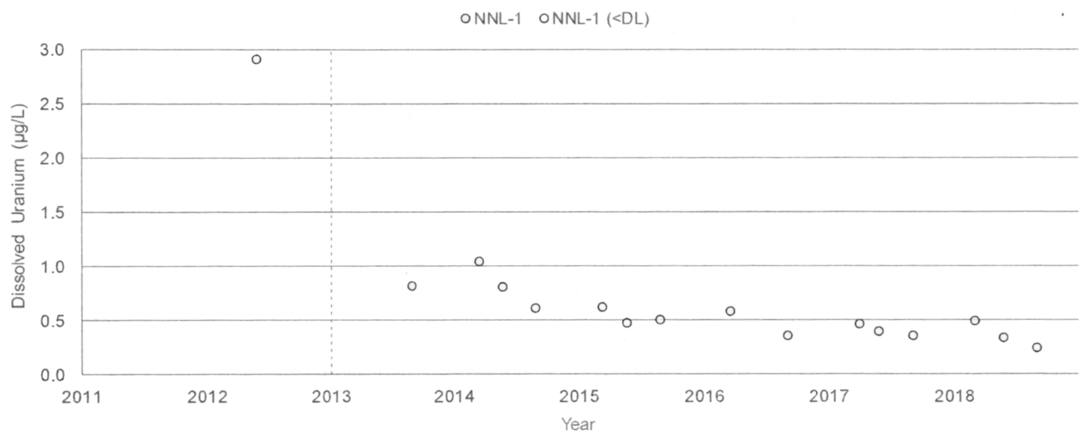
DL = detection limit; < = less than.

Figure VII-162 **Time Series Plot at Station NNL-1 for Dissolved Thallium**



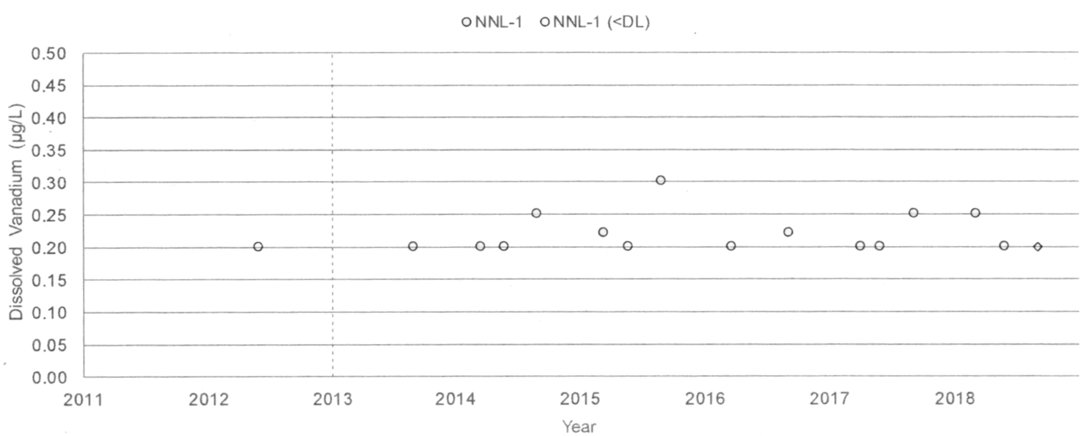
DL = detection limit; < = less than.

Figure VII-163 **Time Series Plot at Station NNL-1 for Dissolved Titanium**



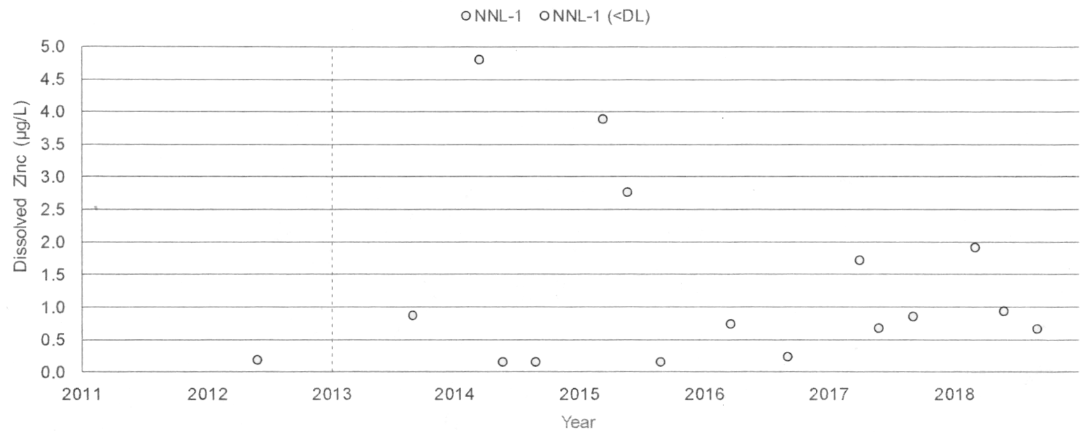
DL = detection limit; < = less than.

Figure VII-164 **Time Series Plot at Station NNL-1 for Dissolved Uranium**



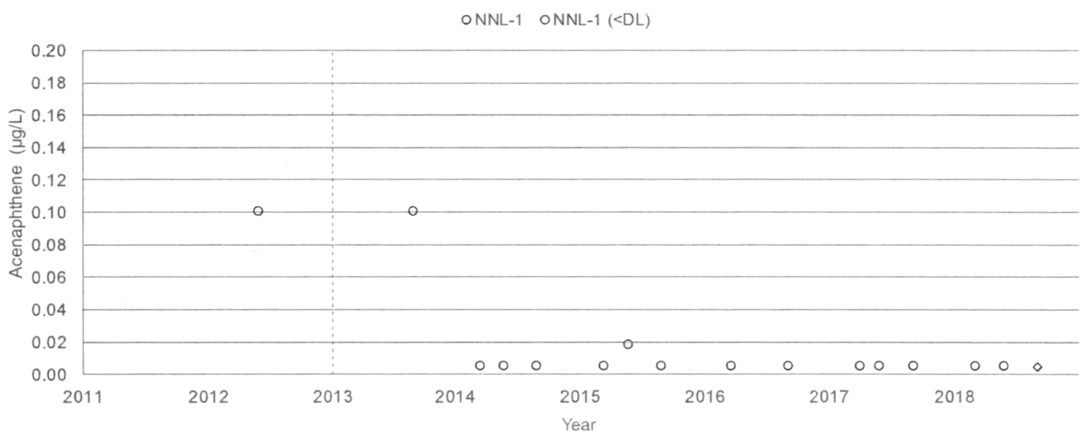
DL = detection limit; < = less than.

Figure VII-165 **Time Series Plot at Station NNL-1 for Dissolved Vanadium**



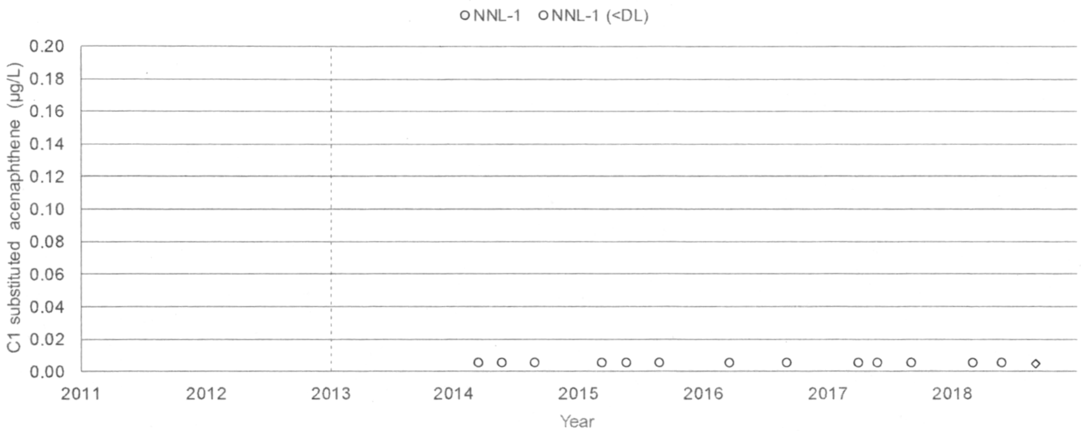
DL = detection limit; < = less than.

Figure VII-166 **Time Series Plot at Station NNL-1 for Dissolved Zinc**



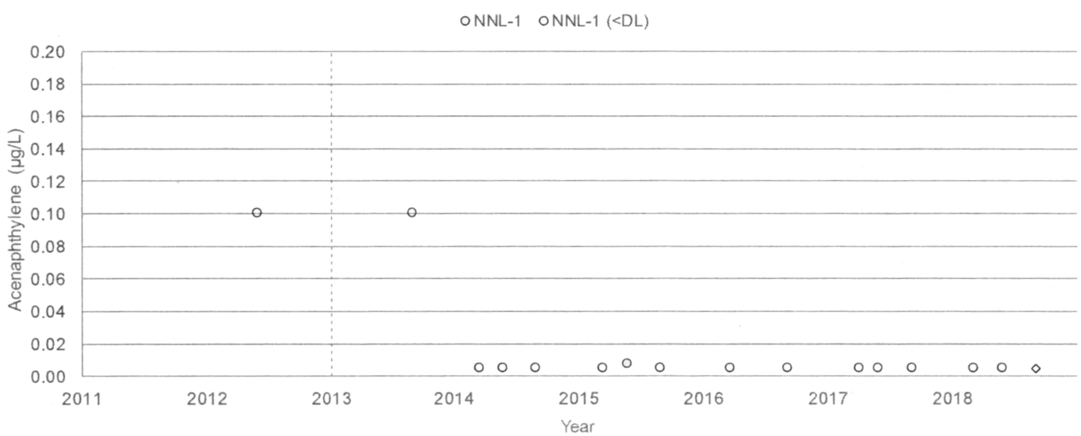
DL = detection limit; < = less than.

Figure VII-167 **Time Series Plot at Station NNL-1 for Acenaphthene**



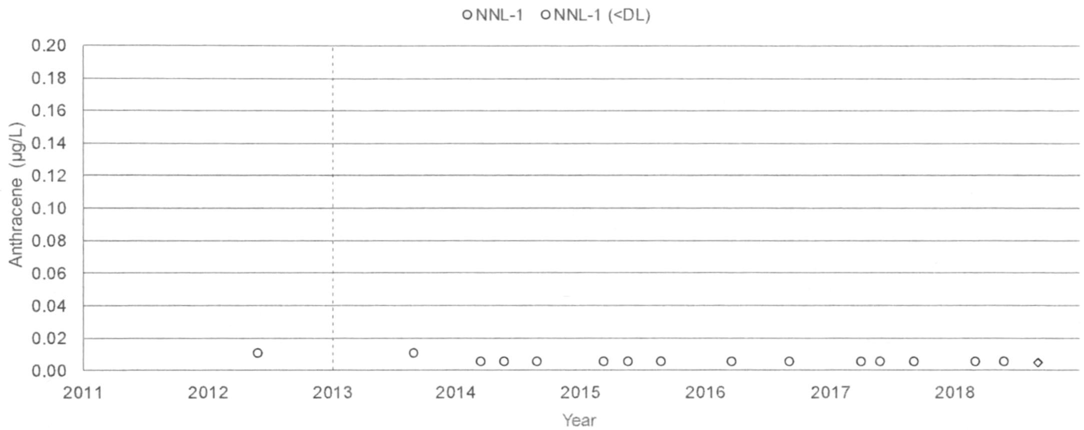
DL = detection limit; < = less than.

Figure VII-168 **Time Series Plot at Station NNL-1 for C1 Substituted Acenaphthene**



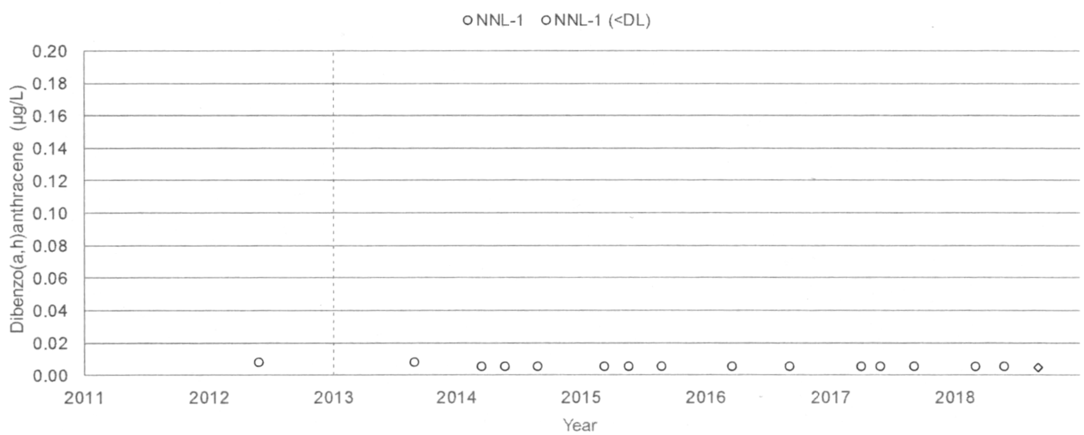
DL = detection limit; < = less than.

Figure VII-169 **Time Series Plot at Station NNL-1 for Acenaphthylene**



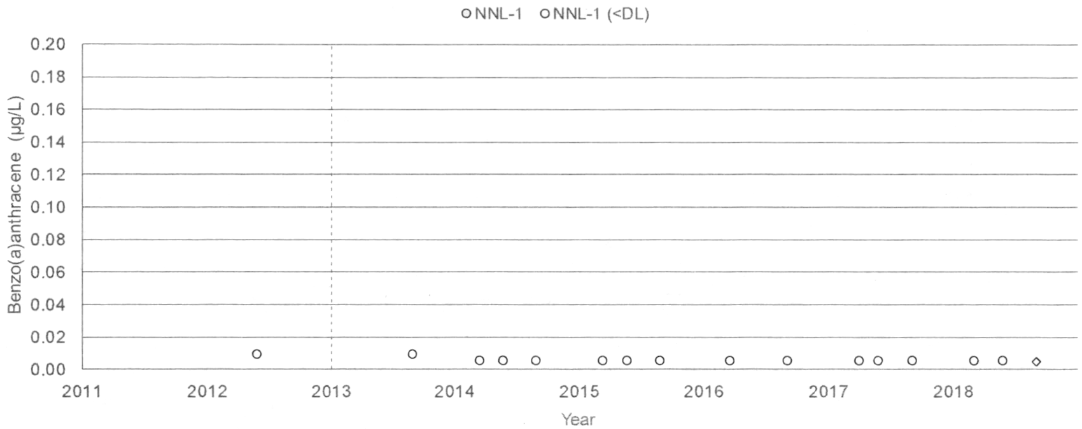
DL = detection limit; < = less than.

Figure VII-170 Time Series Plot at Station NNL-1 for Anthracene



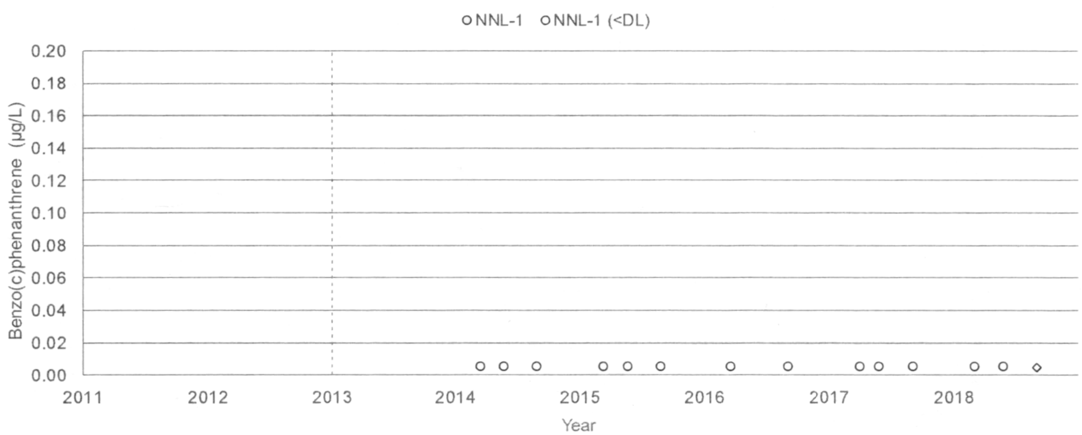
DL = detection limit; < = less than.

Figure VII-171 Time Series Plot at Station NNL-1 for Dibenzo(a,h)anthracene



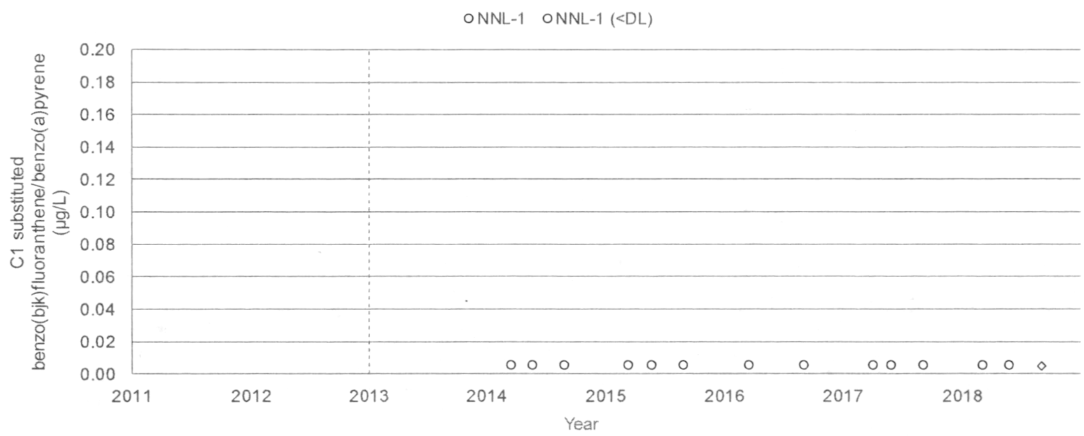
DL = detection limit; < = less than.

Figure VII-172 Time Series Plot at Station NNL-1 for Benzo(a)anthracene



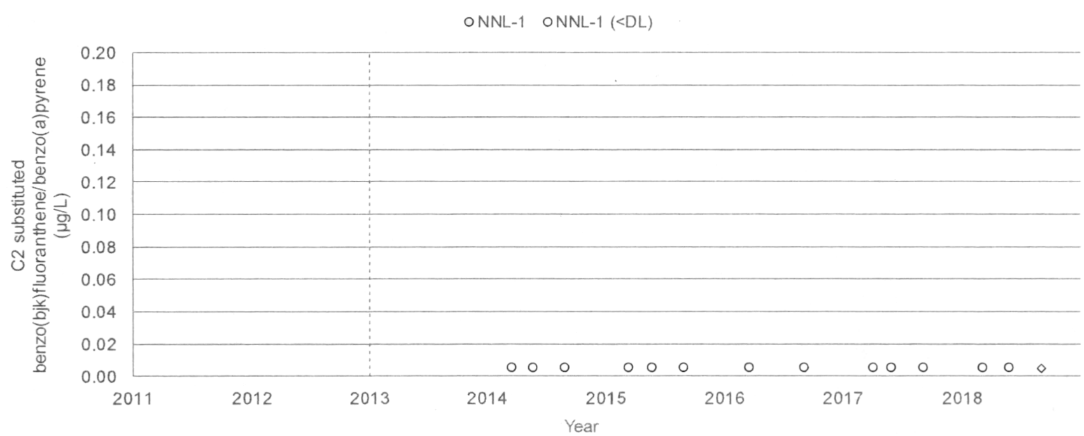
DL = detection limit; < = less than.

Figure VII-173 Time Series Plot at Station NNL-1 for Benzo(c)phenanthrene



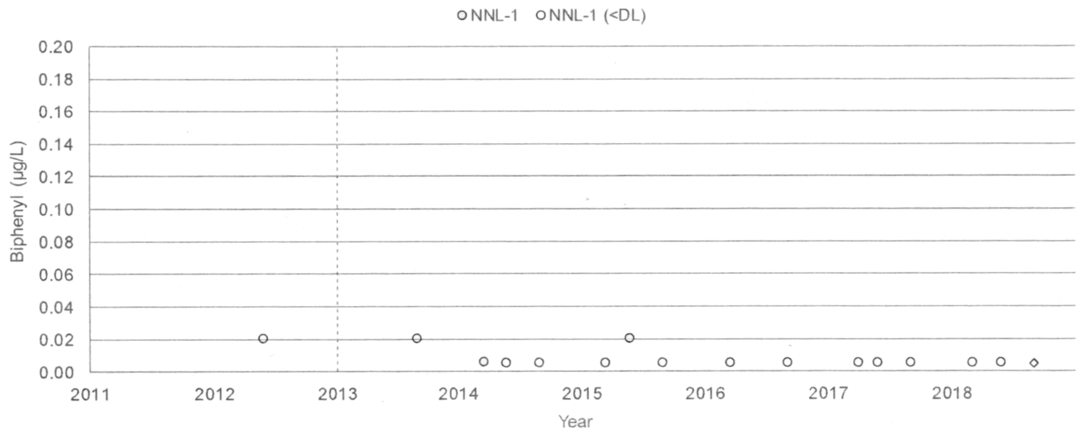
DL = detection limit; < = less than.

Figure VII-174 **Time Series Plot at Station NNL-1 for C1 Substituted Benzo(bjk)fluoranthene/benzo(a)pyrene**



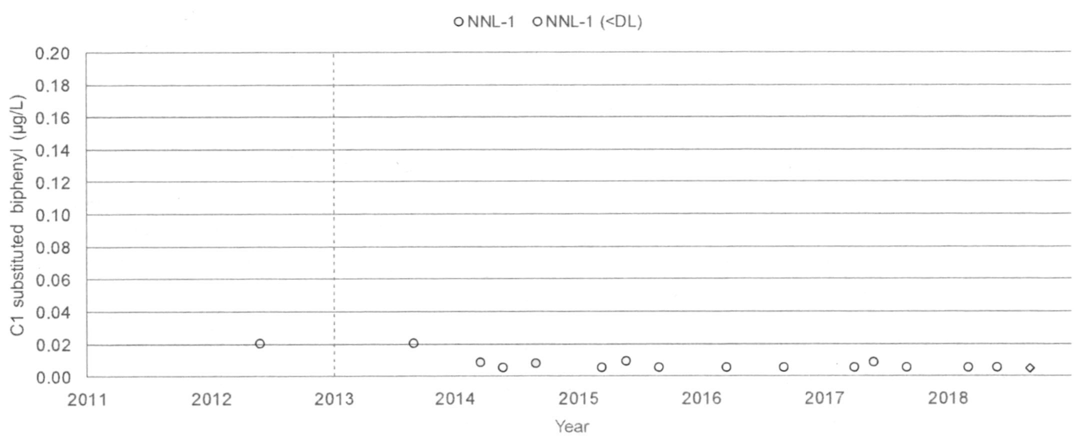
DL = detection limit; < = less than.

Figure VII-175 **Time Series Plot at Station NNL-1 for C2 Substituted Benzo(bjk)fluoranthene/benzo(a)pyrene**



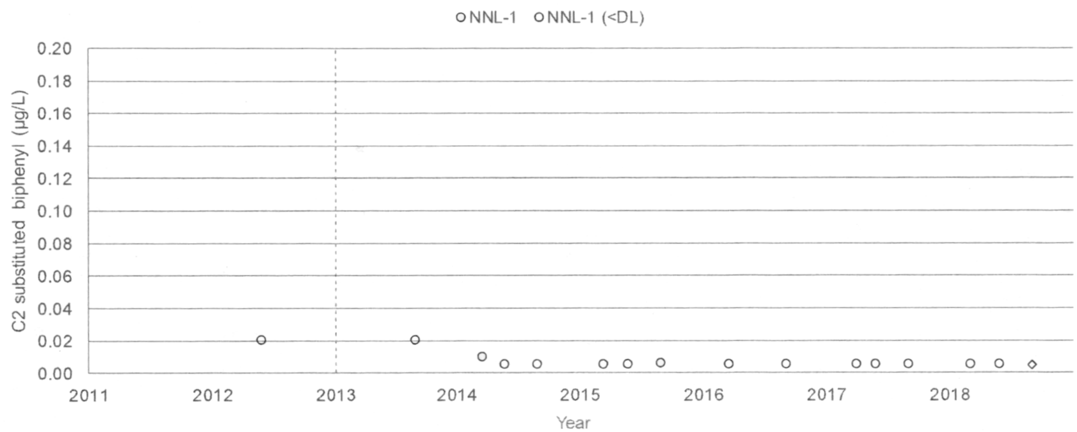
DL = detection limit; < = less than.

Figure VII-176 **Time Series Plot at Station NNL-1 for Biphenyl**



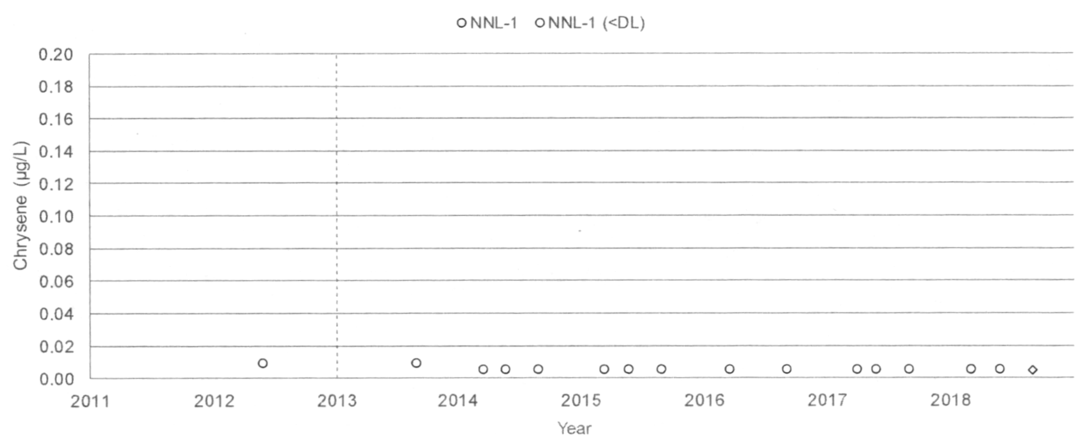
DL = detection limit; < = less than.

Figure VII-177 **Time Series Plot at Station NNL-1 for C1 Substituted Biphenyl**



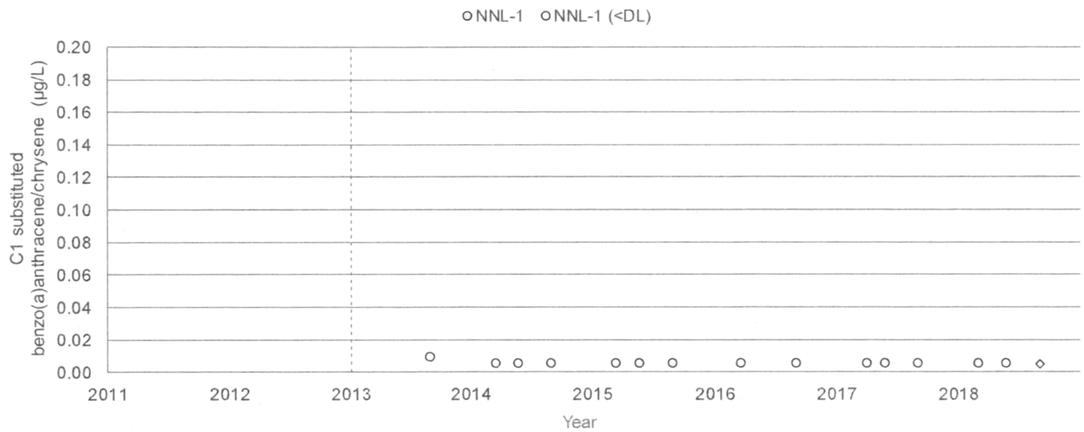
DL = detection limit; < = less than.

Figure VII-178 Time Series Plot at Station NNL-1 for C2 Substituted Biphenyl



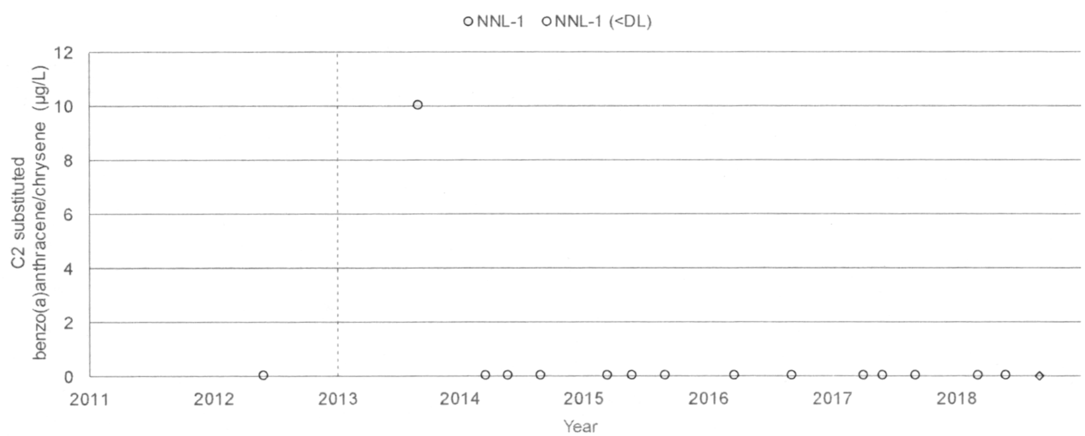
DL = detection limit; < = less than.

Figure VII-179 Time Series Plot at Station NNL-1 for Chrysene



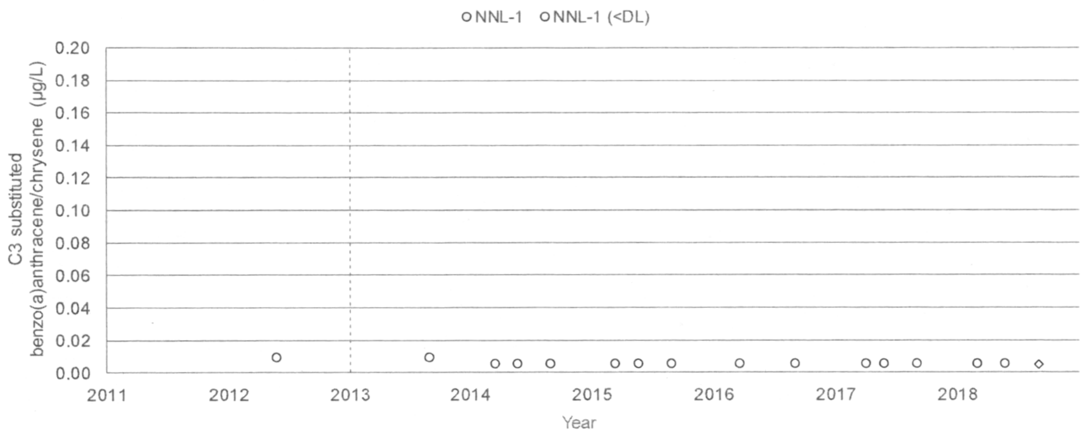
DL = detection limit; < = less than.

Figure VII-180 Time Series Plot at Station NNL-1 for C1 Substituted Benzo(a)anthracene/chrysene



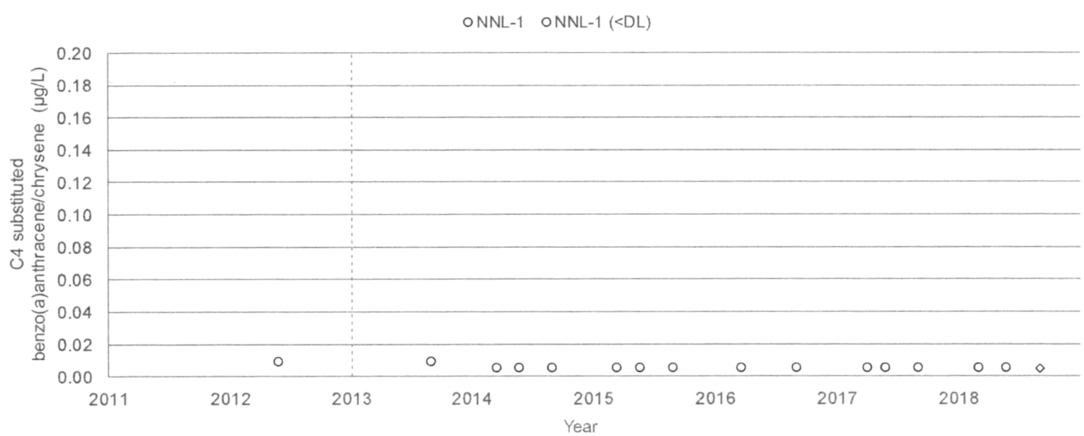
DL = detection limit; < = less than.

Figure VII-181 Time Series Plot at Station NNL-1 for C2 Substituted Benzo(a)anthracene/chrysene



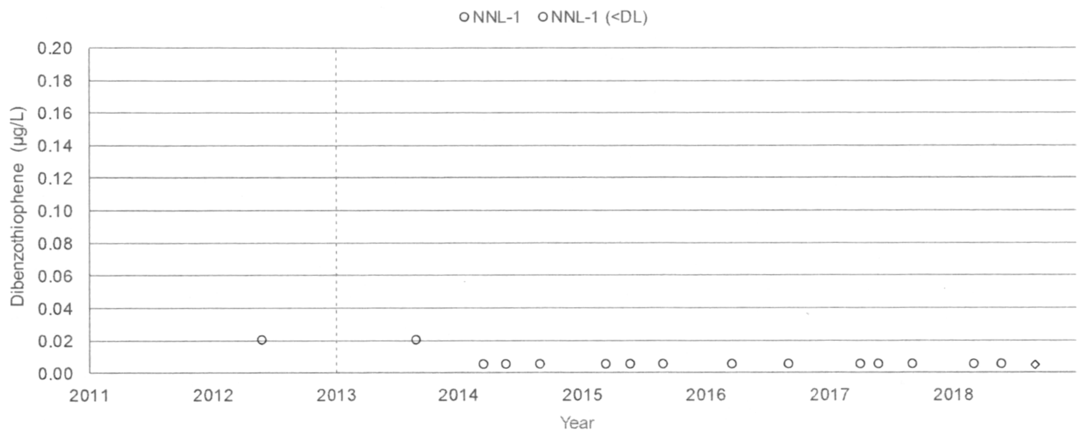
DL = detection limit; < = less than.

Figure VII-182 Time Series Plot at Station NNL-1 for C3 Substituted Benzo(a)anthracene/chrysene



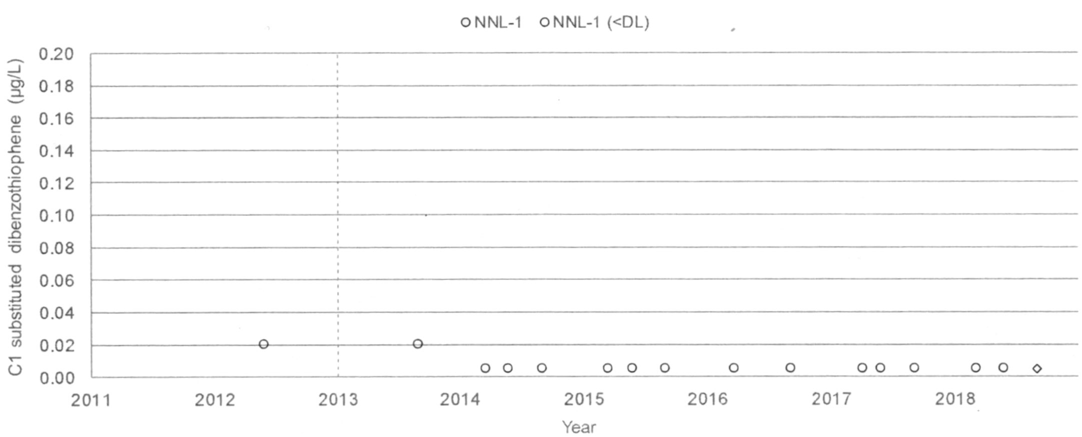
DL = detection limit; < = less than.

Figure VII-183 Time Series Plot at Station NNL-1 for C4 Substituted Benzo(a)anthracene/chrysene



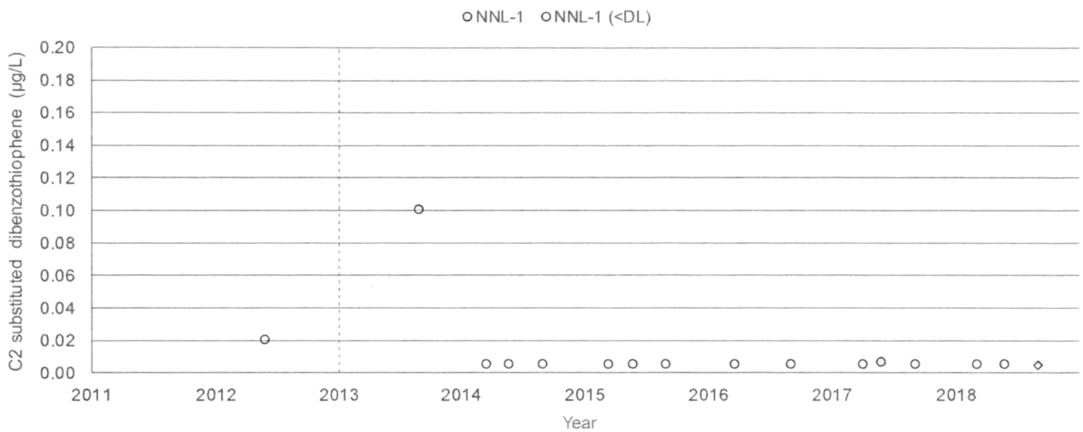
DL = detection limit; < = less than.

Figure VII-184 **Time Series Plot at Station NNL-1 for Dibenzothiophene**



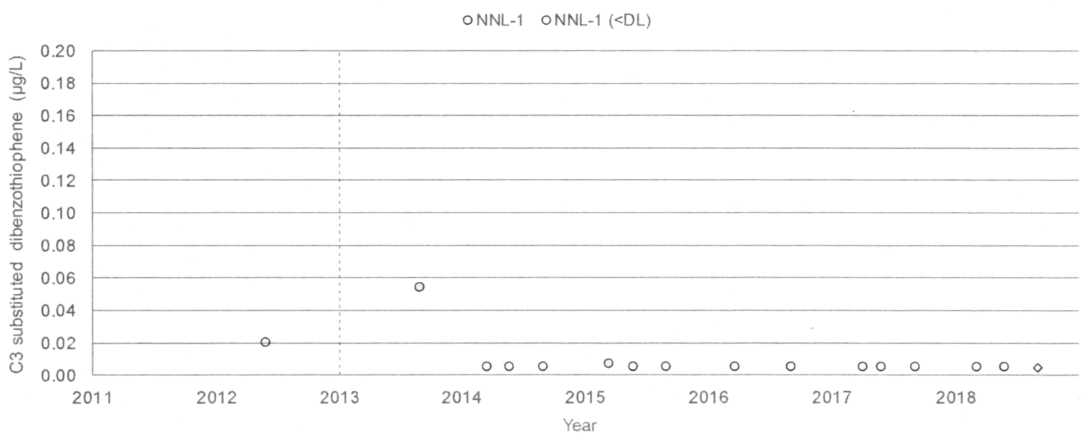
DL = detection limit; < = less than.

Figure VII-185 **Time Series Plot at Station NNL-1 for C1 Substituted Dibenzothiophene**



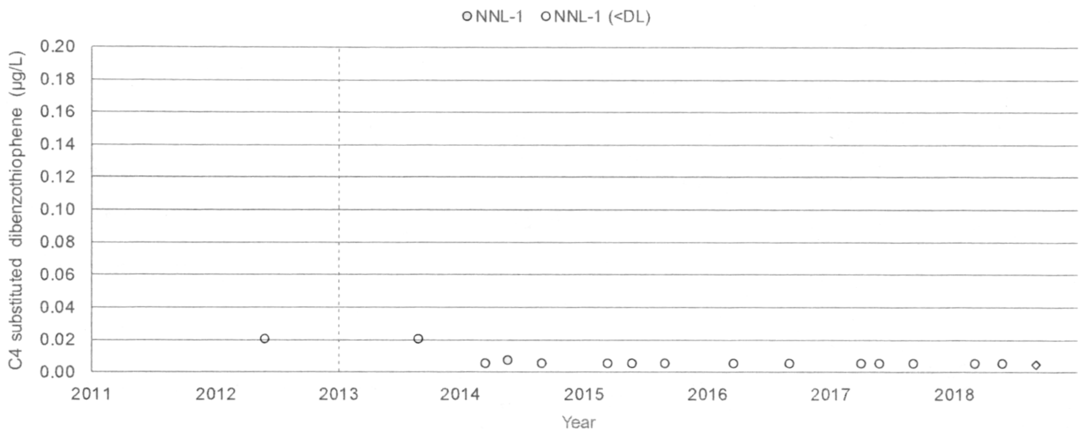
DL = detection limit; < = less than.

Figure VII-186 **Time Series Plot at Station NNL-1 for C2 Substituted Dibenzothiophene**



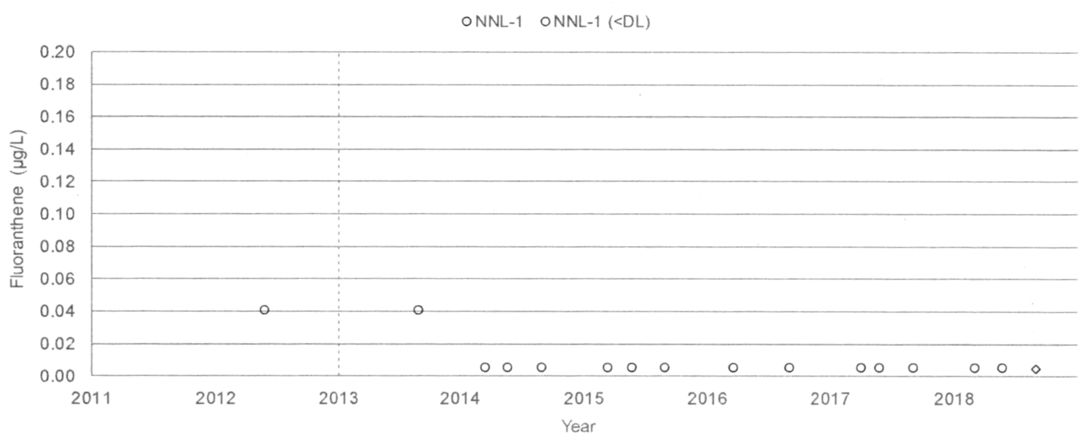
DL = detection limit; < = less than.

Figure VII-187 **Time Series Plot at Station NNL-1 for C3 Substituted Dibenzothiophene**



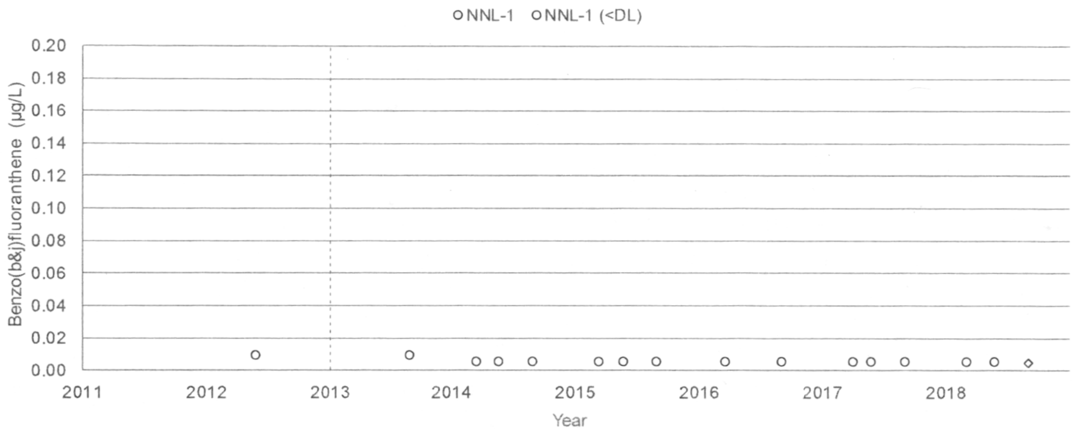
DL = detection limit; < = less than.

Figure VII-188 Time Series Plot at Station NNL-1 for C4 Substituted Dibenzothiophene



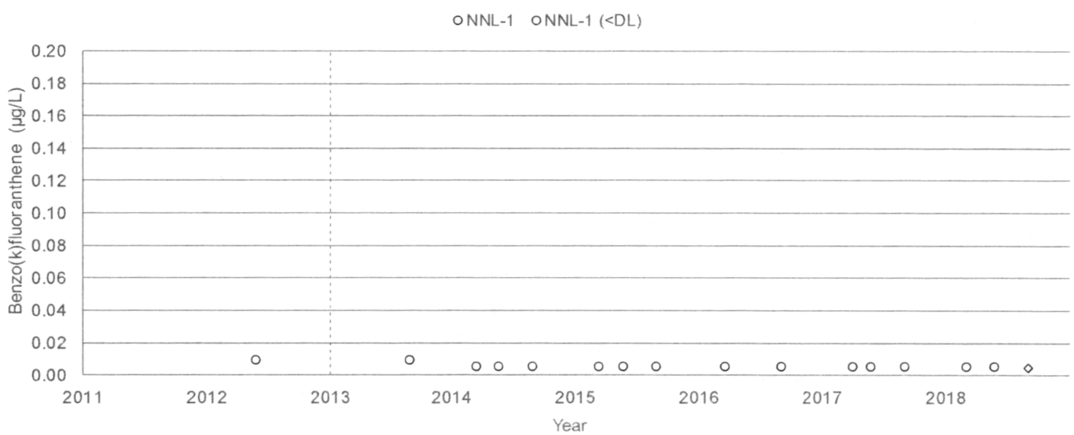
DL = detection limit; < = less than.

Figure VII-189 Time Series Plot at Station NNL-1 for Fluoranthene



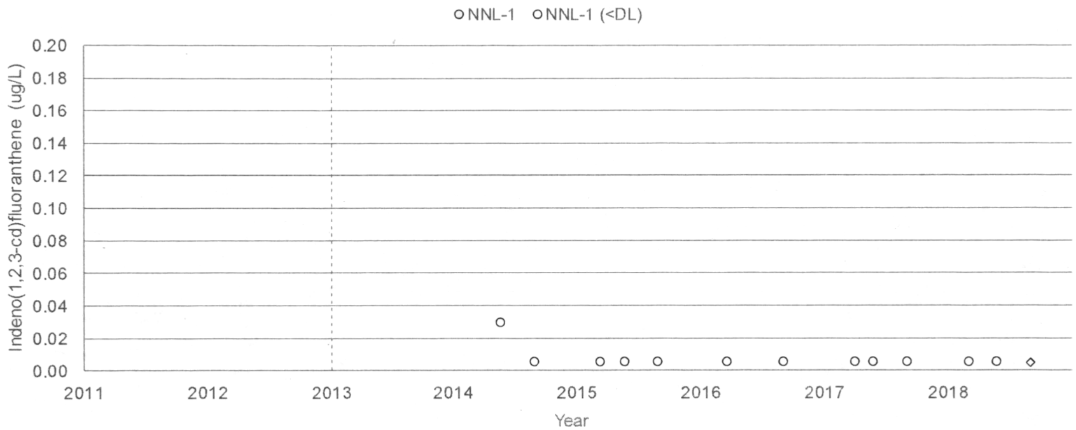
DL = detection limit; < = less than.

Figure VII-190 Time Series Plot at Station NNL-1 for Benzo(b&j)fluoranthene



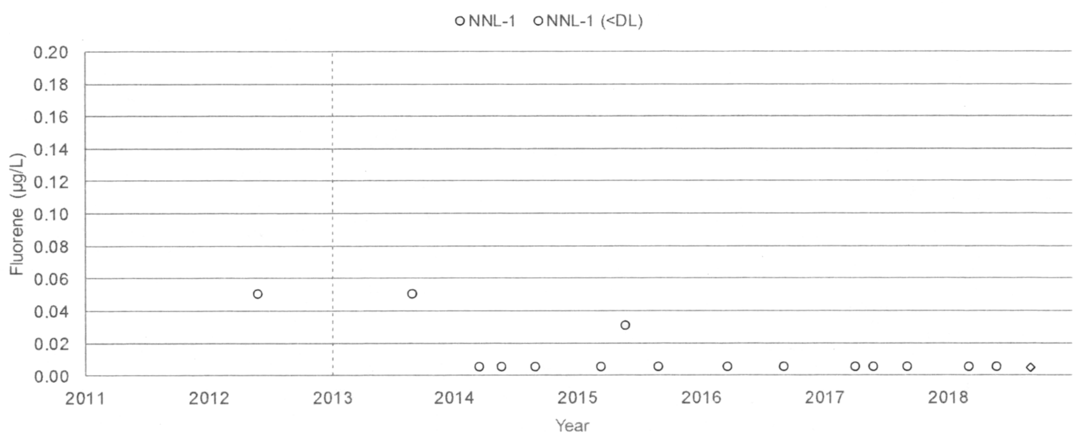
DL = detection limit; < = less than.

Figure VII-191 Time Series Plot at Station NNL-1 for Benzo(k)fluoranthene



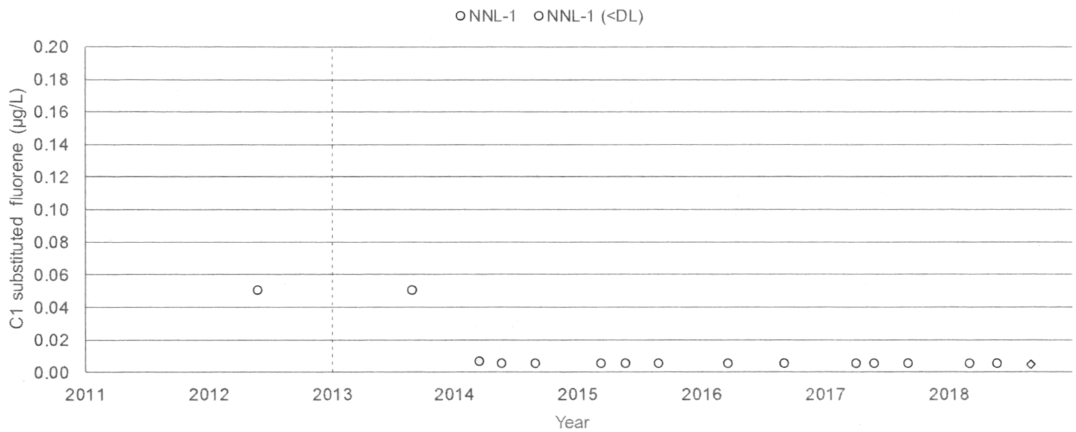
DL = detection limit; < = less than.

Figure VII-192 Time Series Plot at Station NNL-1 for Indeno(1,2,3-cd)fluoranthene



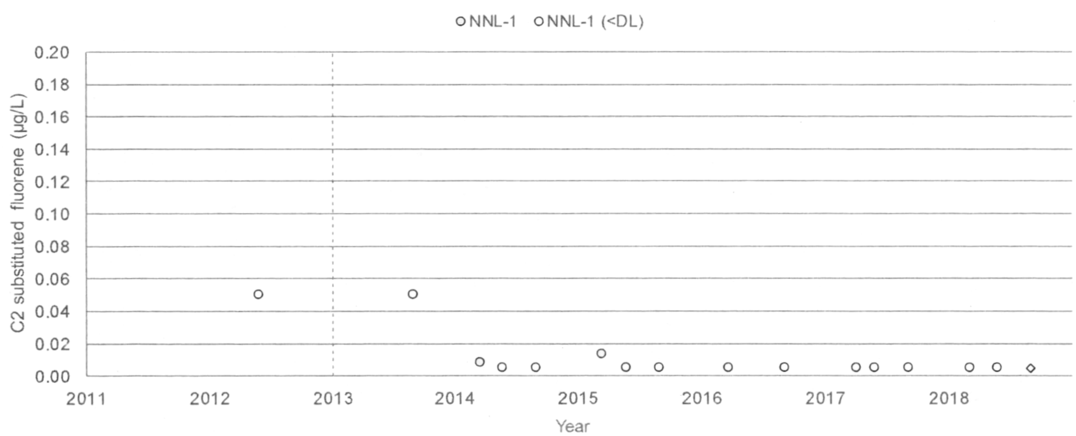
DL = detection limit; < = less than.

Figure VII-193 Time Series Plot at Station NNL-1 for Fluorene



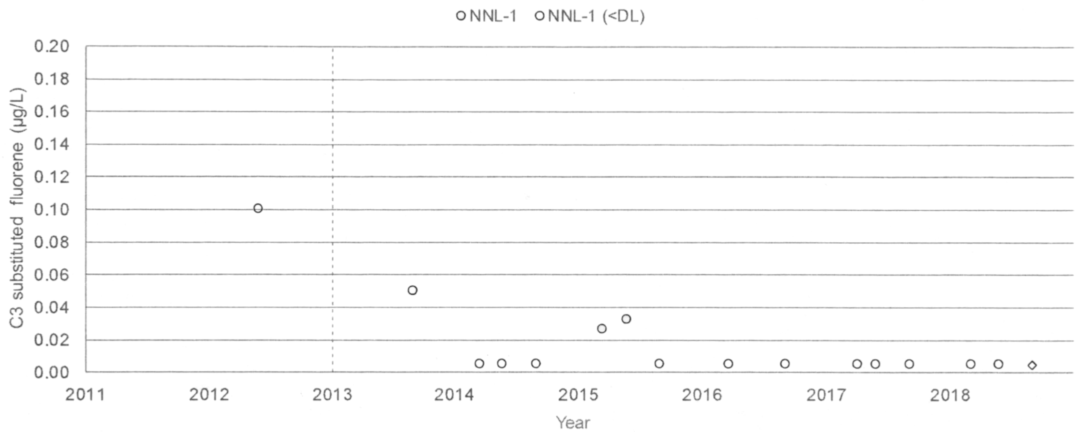
DL = detection limit; < = less than.

Figure VII-194 Time Series Plot at Station NNL-1 for C1 Substituted Fluorene



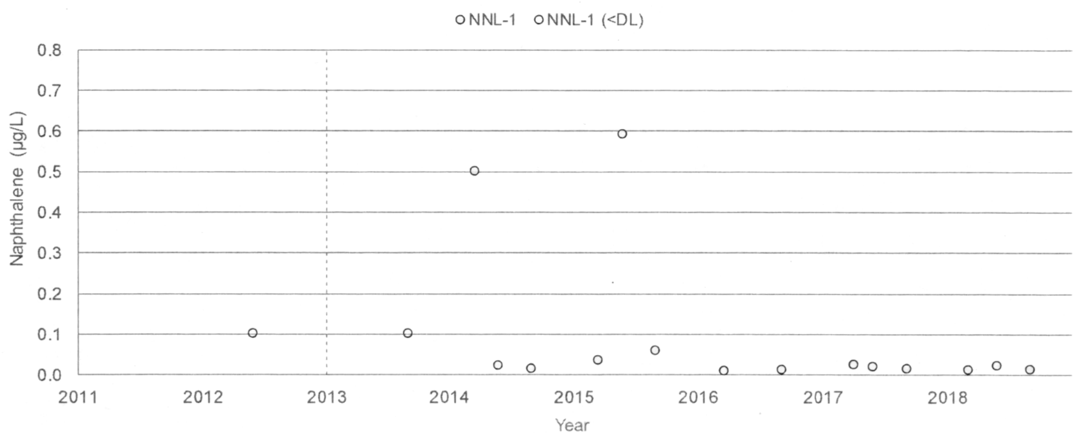
DL = detection limit; < = less than.

Figure VII-195 Time Series Plot at Station NNL-1 for C2 Substituted Fluorene



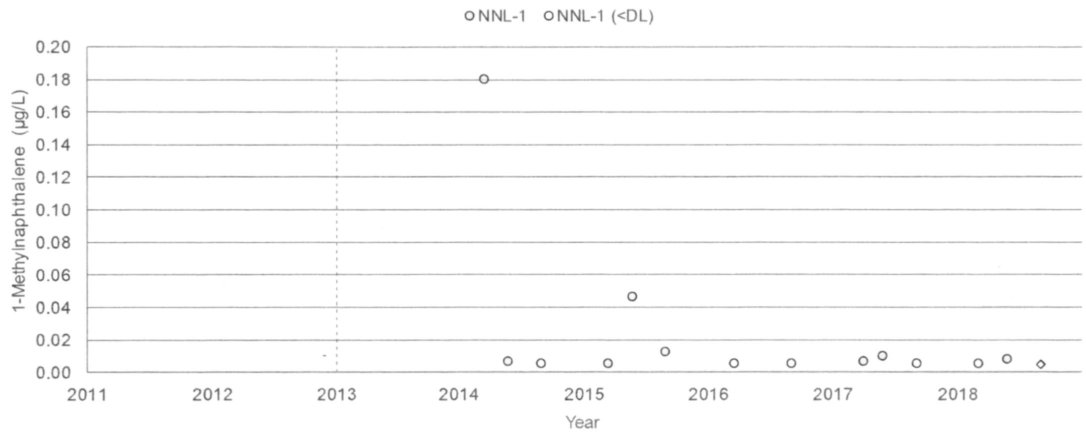
DL = detection limit; < = less than.

Figure VII-196 **Time Series Plot at Station NNL-1 for C3 Substituted Fluorene**



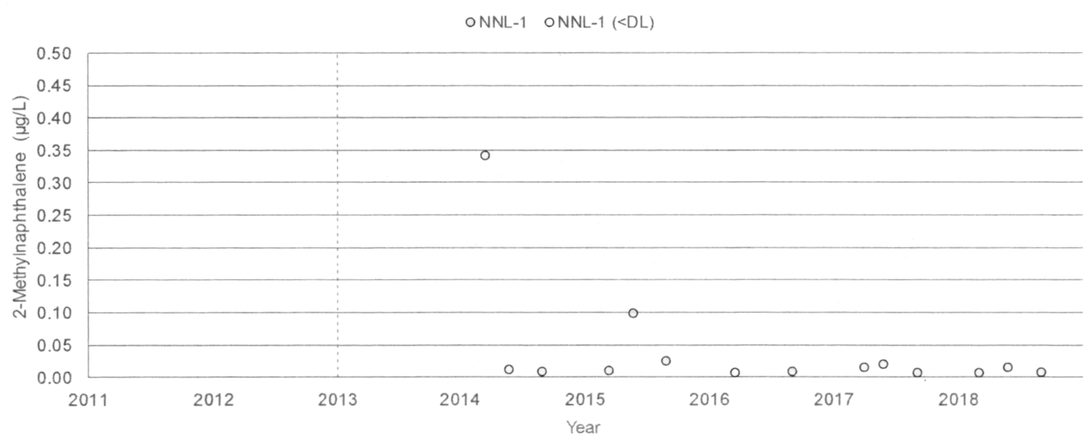
DL = detection limit; < = less than.

Figure VII-197 **Time Series Plot at Station NNL-1 for Naphthalene**



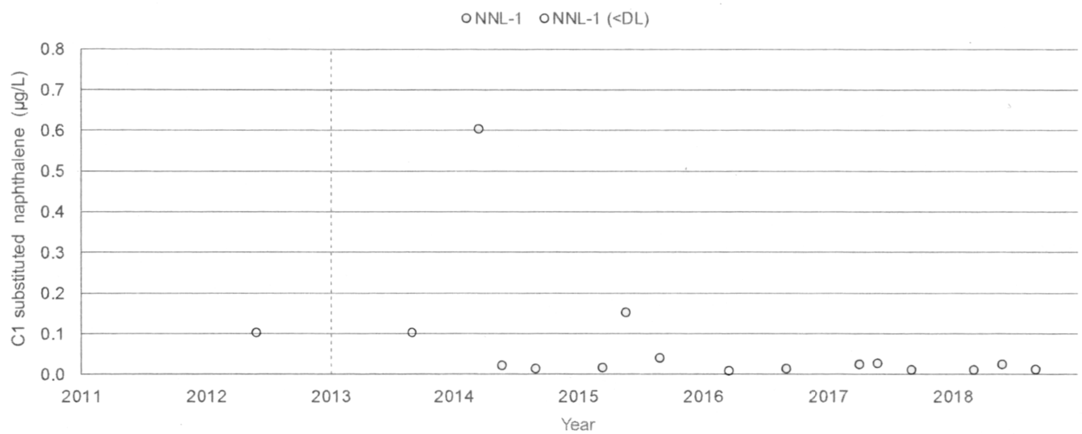
DL = detection limit; < = less than.

Figure VII-198 **Time Series Plot at Station NNL-1 for 1-Methylnaphthalene**



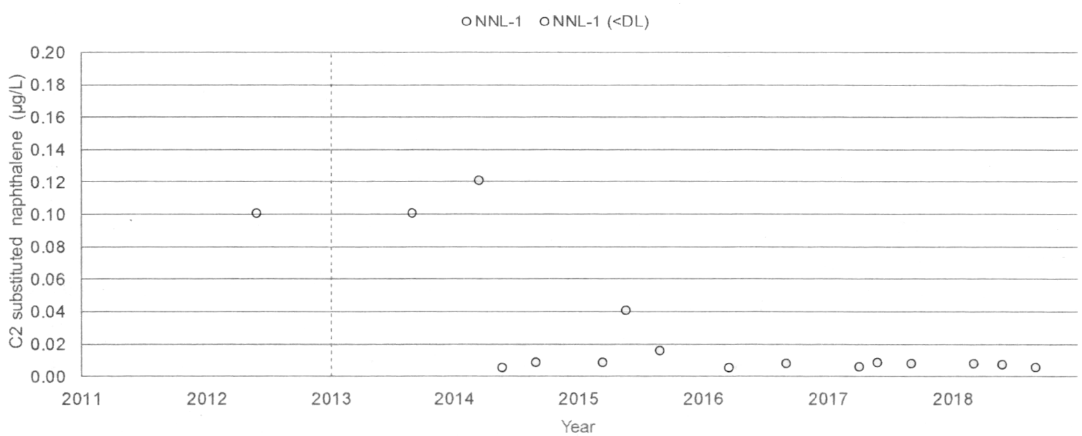
DL = detection limit; < = less than.

Figure VII-199 **Time Series Plot at Station NNL-1 for 2-Methylnaphthalene**



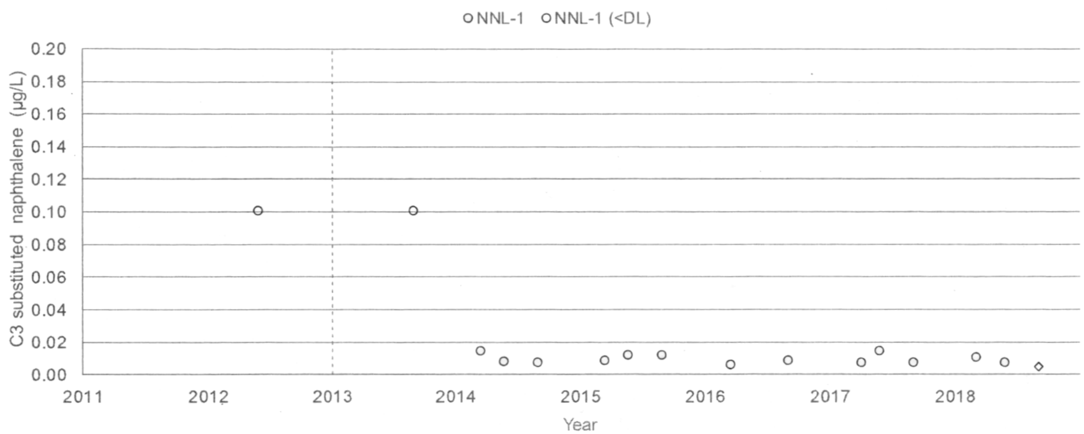
DL = detection limit; < = less than.

Figure VII-200 **Time Series Plot at Station NNL-1 for C1 Substituted Naphthalene**



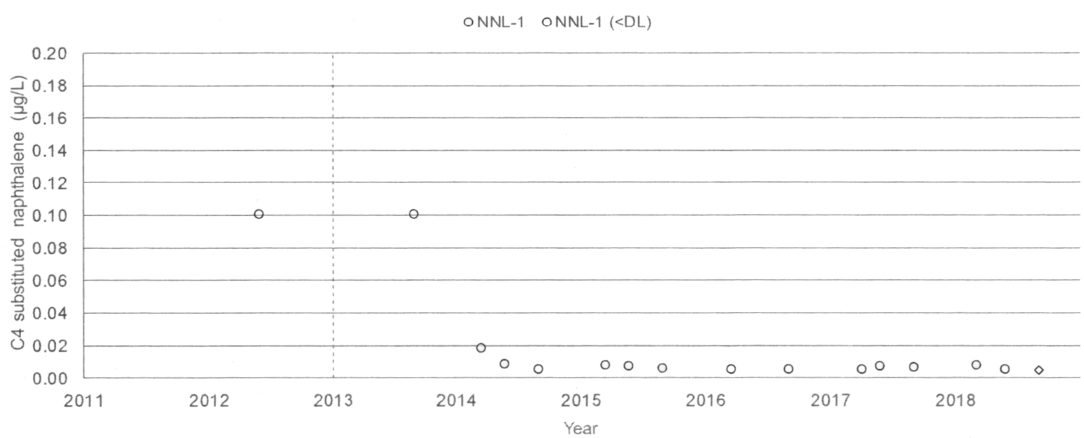
DL = detection limit; < = less than.

Figure VII-201 **Time Series Plot at Station NNL-1 for C2 Substituted Naphthalene**



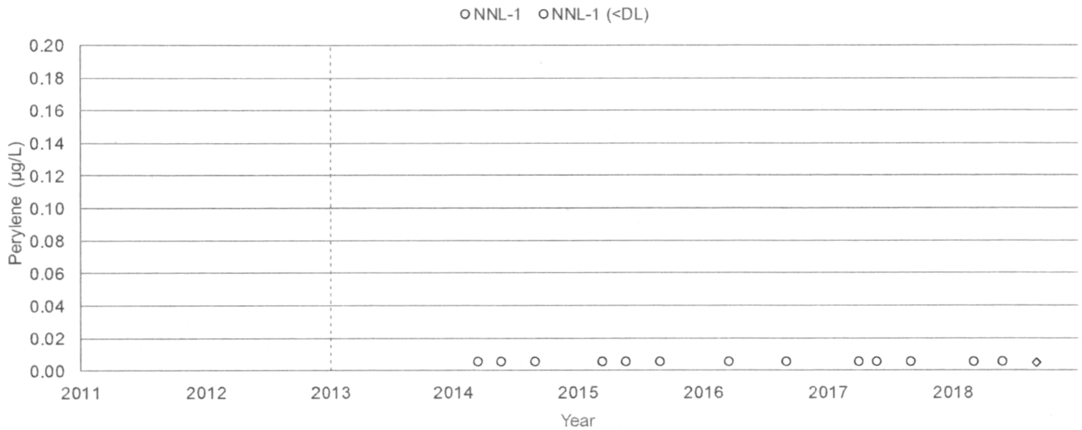
DL = detection limit; < = less than.

Figure VII-202 **Time Series Plot at Station NNL-1 for C3 Substituted Naphthalene**



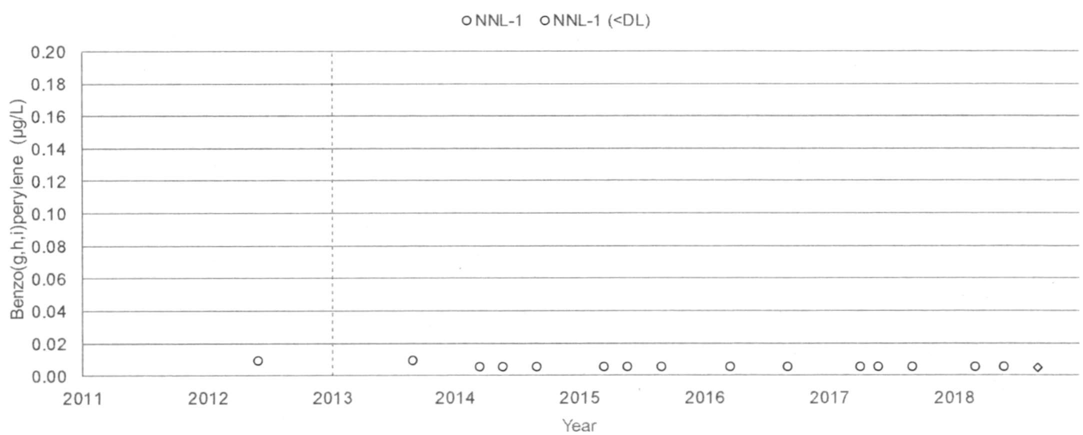
DL = detection limit; < = less than.

Figure VII-203 **Time Series Plot at Station NNL-1 for C4 Substituted Naphthalene**



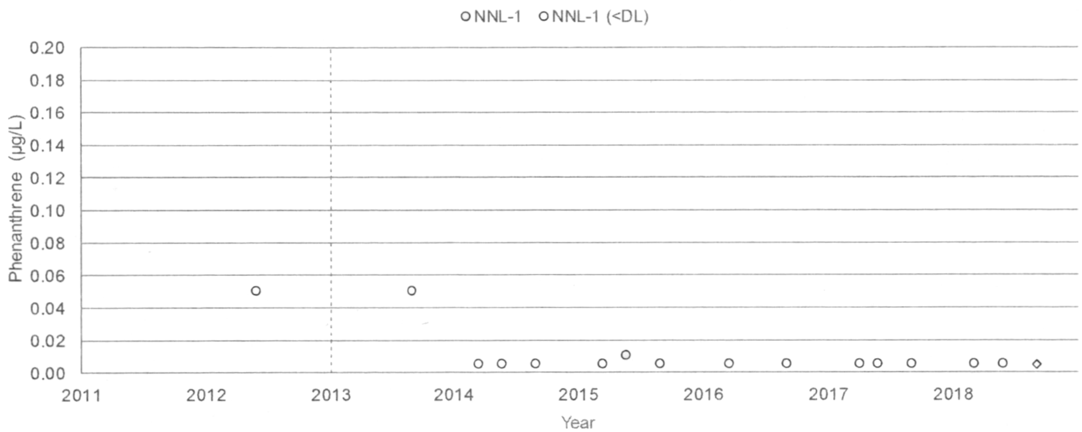
DL = detection limit; < = less than.

Figure VII-204 Time Series Plot at Station NNL-1 for Perylene



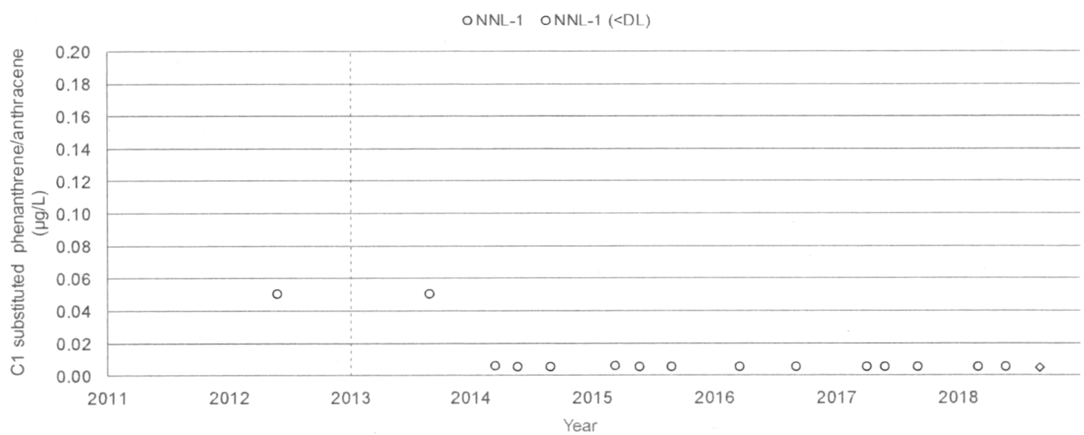
DL = detection limit; < = less than.

Figure VII-205 Time Series Plot at Station NNL-1 for Benzo(g,h,i)perylene



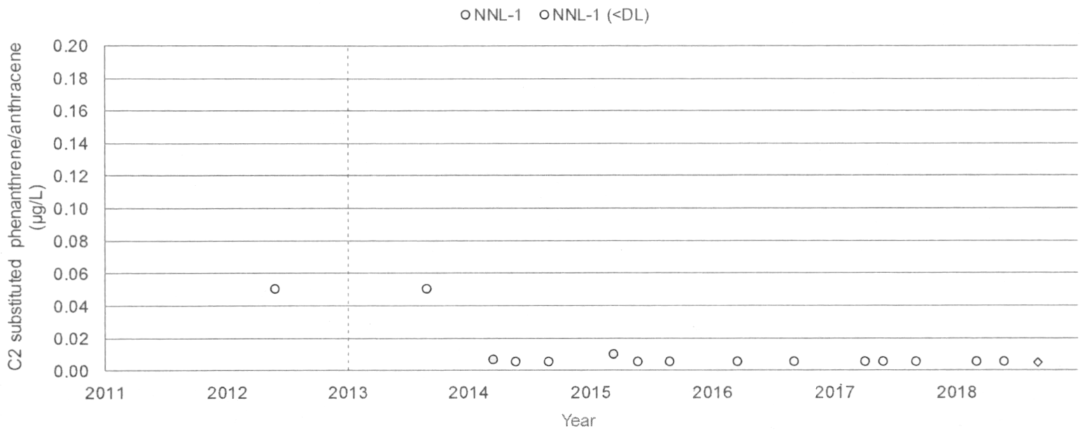
DL = detection limit; < = less than.

Figure VII-206 Time Series Plot at Station NNL-1 for Phenanthrene



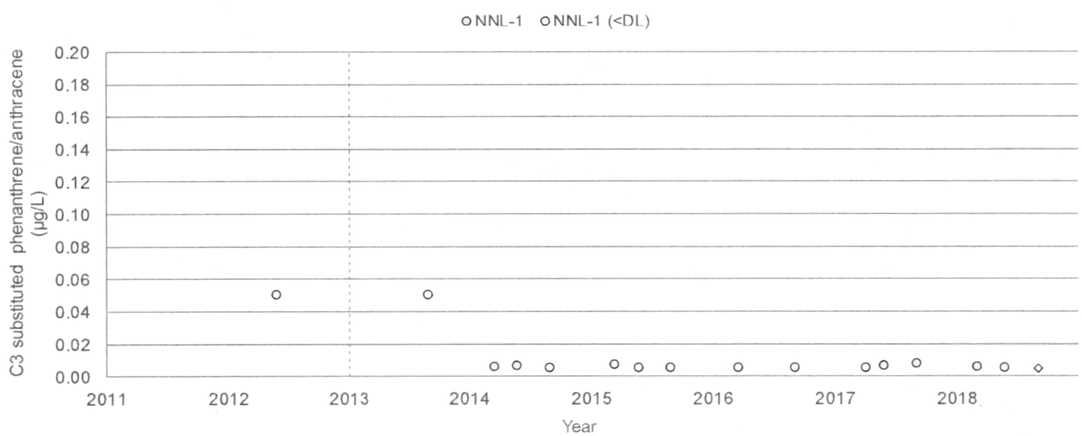
DL = detection limit; < = less than.

Figure VII-207 Time Series Plot at Station NNL-1 for C1 Substituted Phenanthrene/anthracene



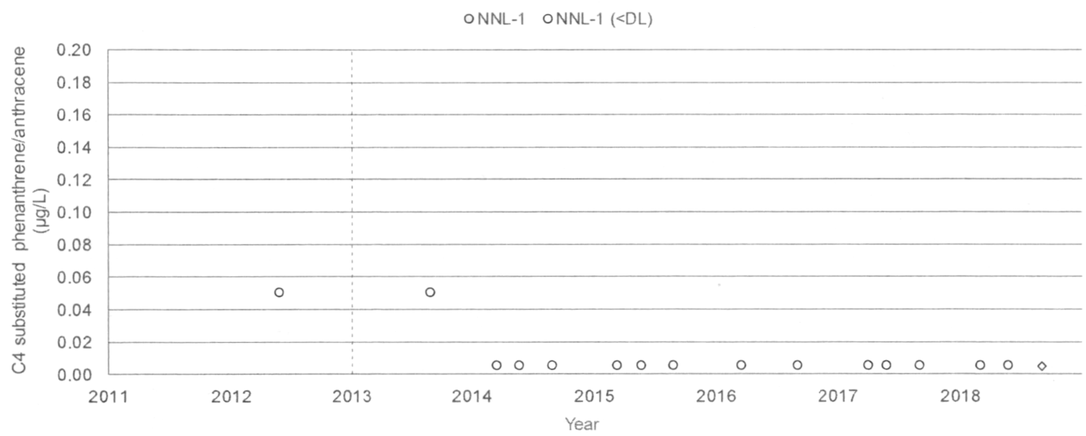
DL = detection limit; < = less than.

Figure VII-208 **Time Series Plot at Station NNL-1 for C2 Substituted Phenanthrene/anthracene**



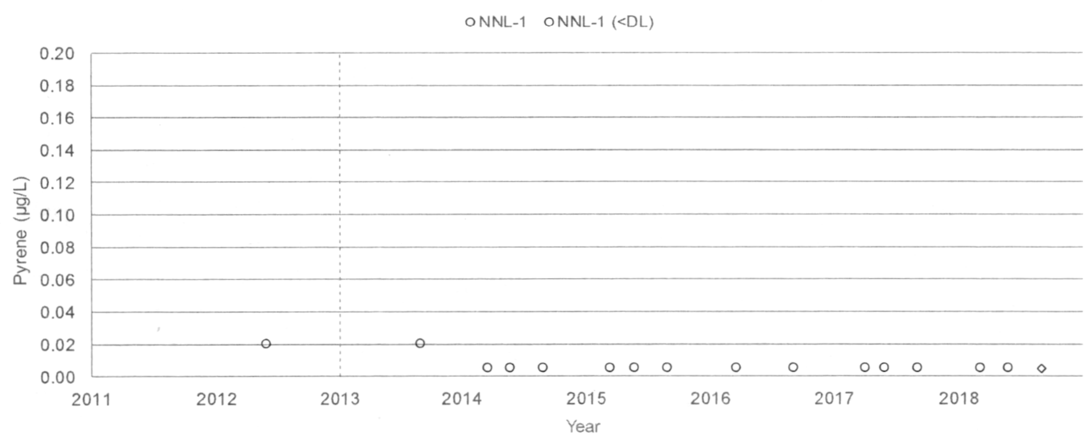
DL = detection limit; < = less than.

Figure VII-209 **Time Series Plot at Station NNL-1 for C3 Substituted Phenanthrene/anthracene**



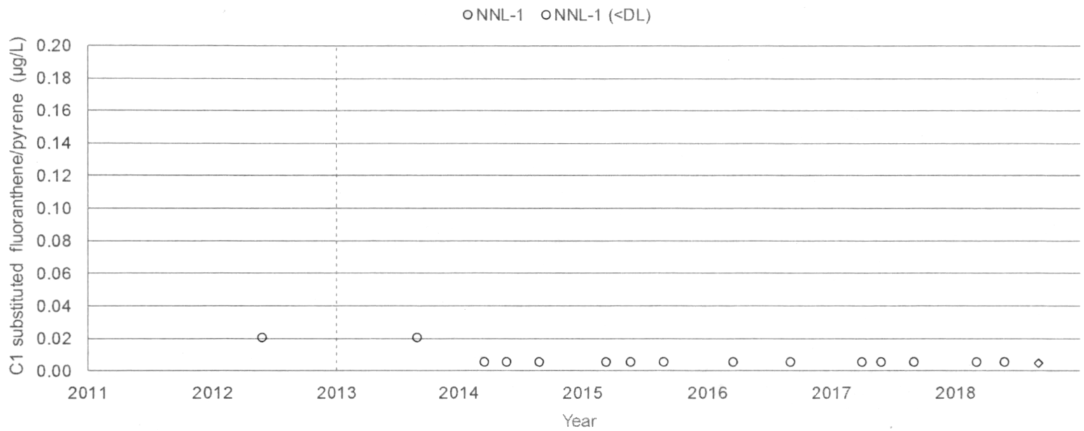
DL = detection limit; < = less than.

Figure VII-210 **Time Series Plot at Station NNL-1 for C4 Substituted Phenanthrene/anthracene**



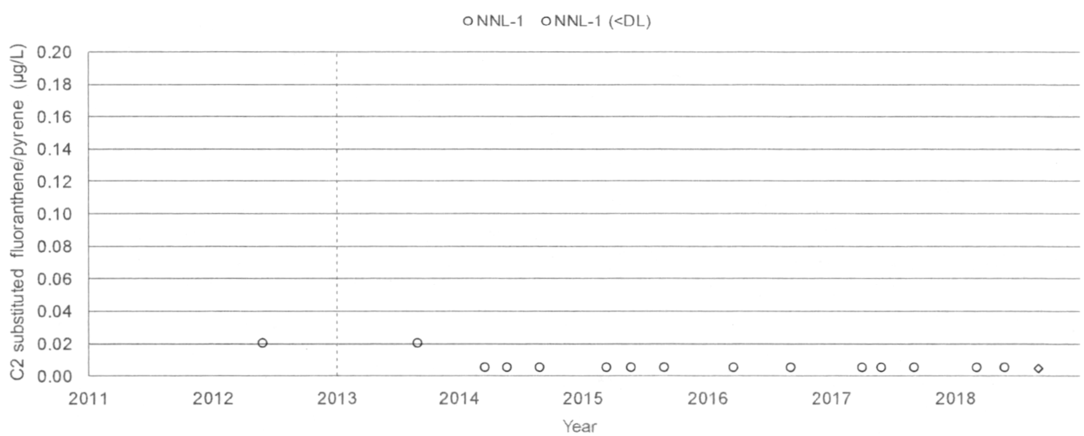
DL = detection limit; < = less than.

Figure VII-211 **Time Series Plot at Station NNL-1 for Pyrene**



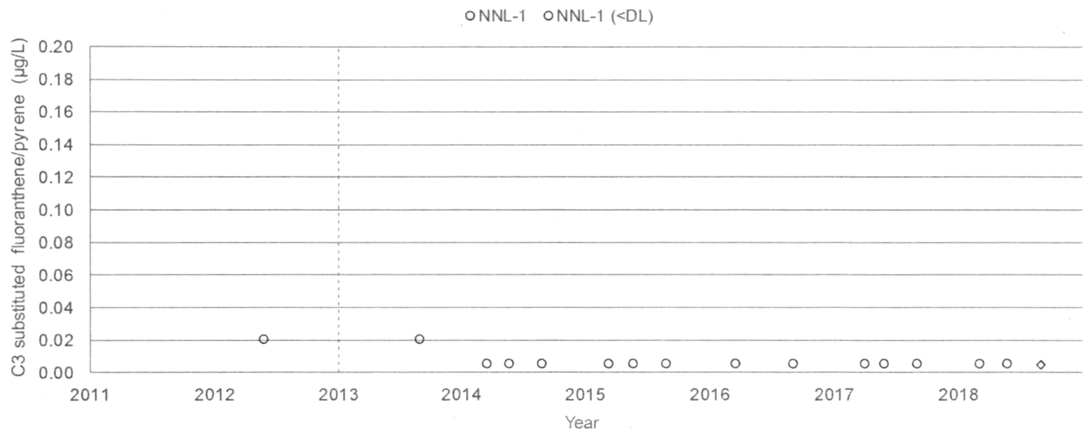
DL = detection limit; < = less than.

Figure VII-212 **Time Series Plot at Station NNL-1 for C1 Substituted Fluoranthene/pyrene**



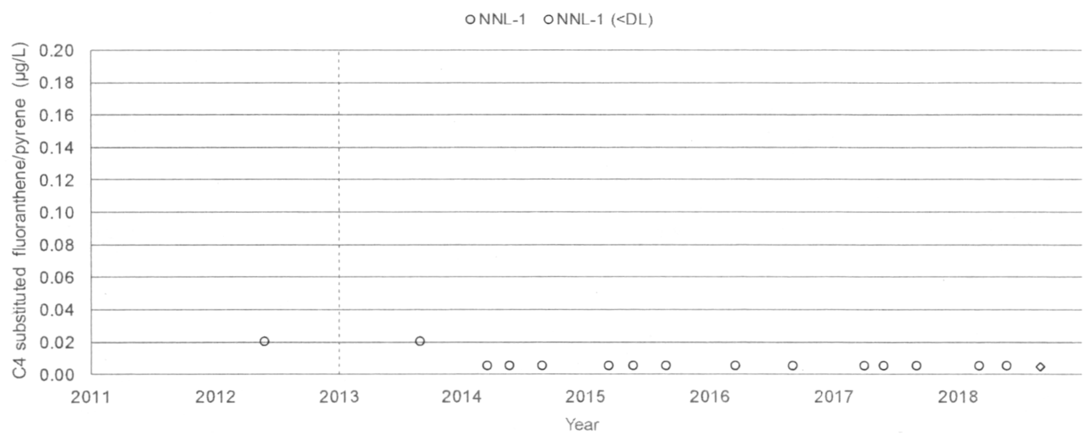
DL = detection limit; < = less than.

Figure VII-213 **Time Series Plot at Station NNL-1 for C2 Substituted Fluoranthene/pyrene**



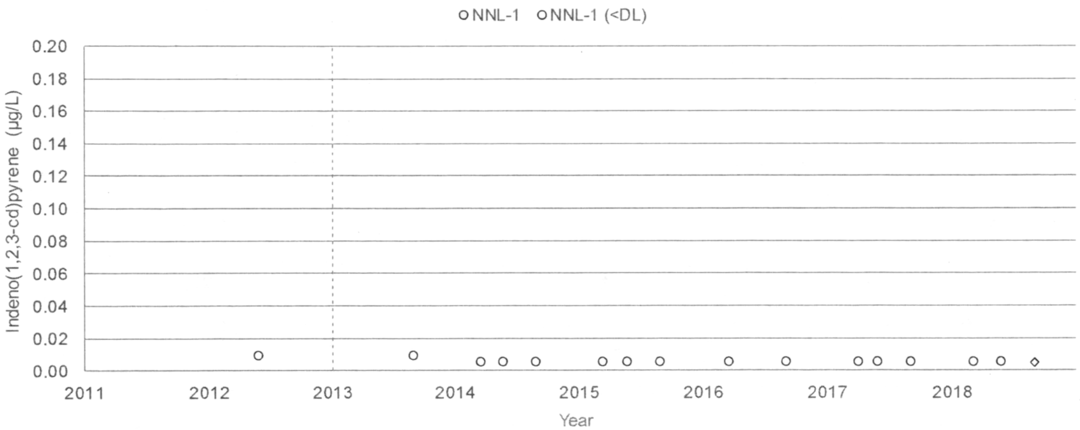
DL = detection limit; < = less than.

Figure VII-214 **Time Series Plot at Station NNL-1 for C3 Substituted Fluoranthene/pyrene**



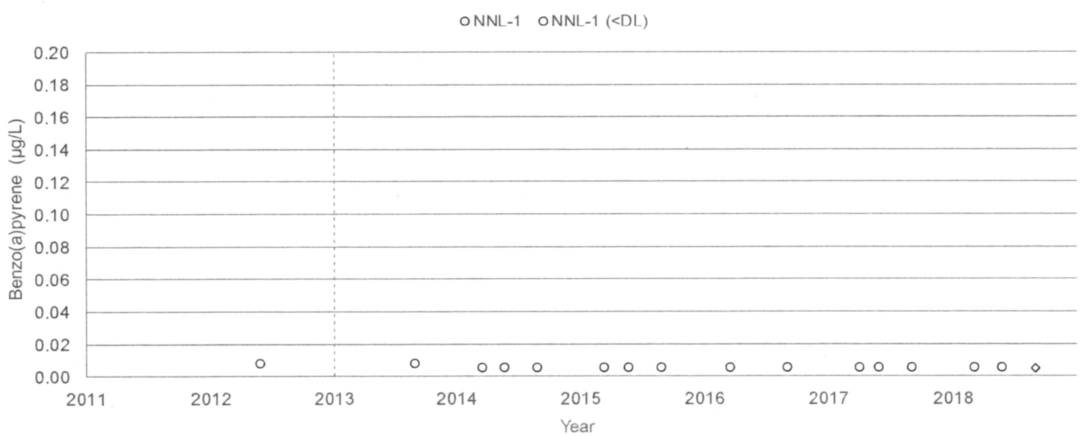
DL = detection limit; < = less than.

Figure VII-215 **Time Series Plot at Station NNL-1 for C4 Substituted Fluoranthene/pyrene**



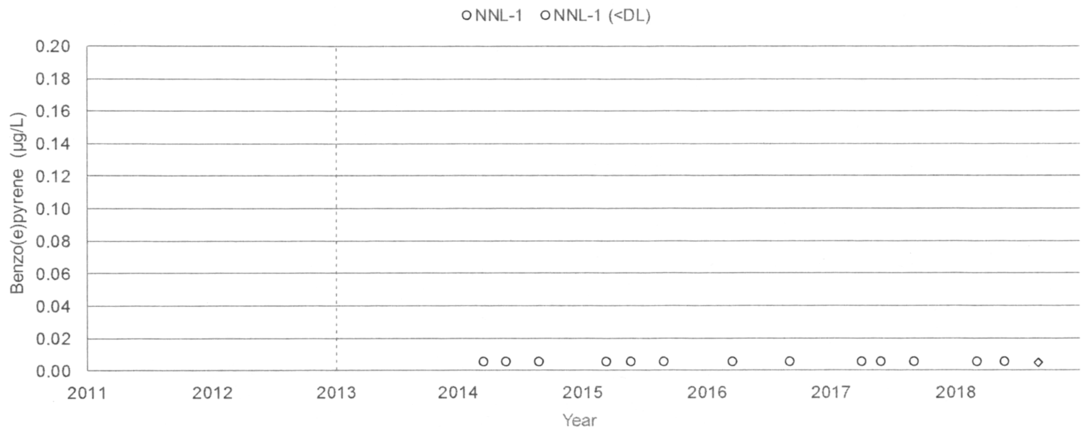
DL = detection limit; < = less than.

Figure VII-216 **Time Series Plot at Station NNL-1 for Indeno(1,2,3-cd)pyrene**



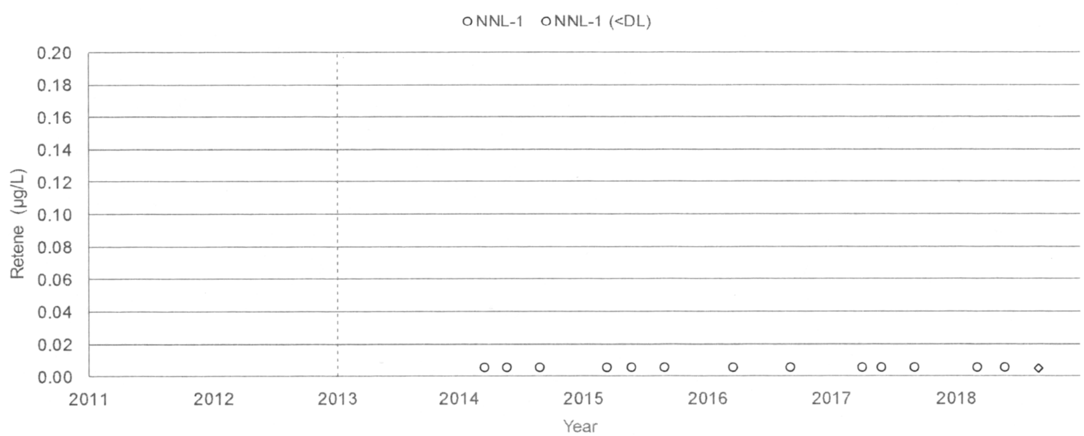
DL = detection limit; < = less than.

Figure VII-217 **Time Series Plot at Station NNL-1 for Benzo(a)pyrene**



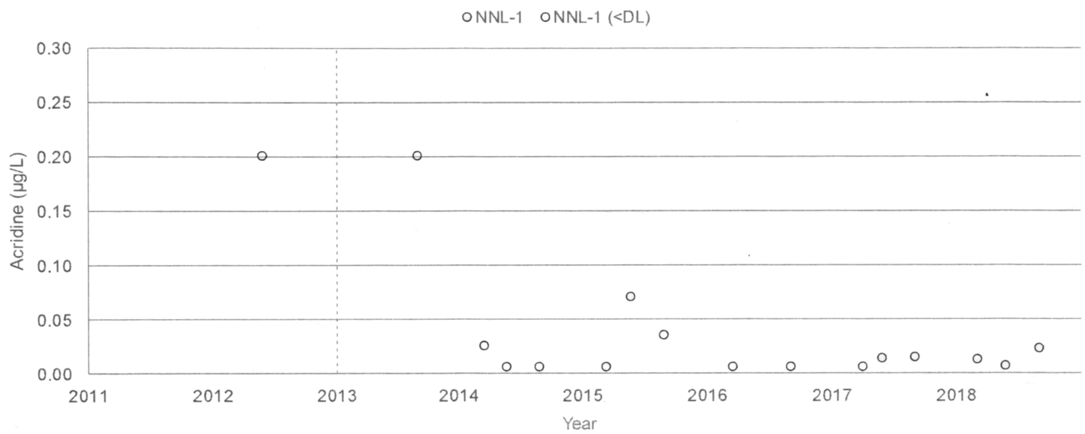
DL = detection limit; < = less than.

Figure VII-218 **Time Series Plot at Station NNL-1 for Benzo(e)pyrene**



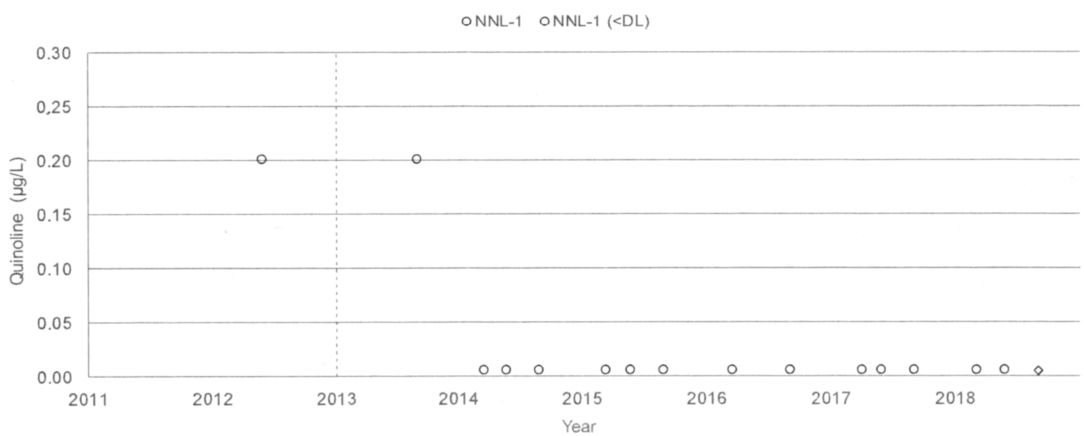
DL = detection limit; < = less than.

Figure VII-219 **Time Series Plot at Station NNL-1 for Retene**



DL = detection limit; < = less than.

Figure VII-220 **Time Series Plot at Station NNL-1 for Acridine**



DL = detection limit; < = less than.

Figure VII-221 **Time Series Plot at Station NNL-1 for Quinoline**

APPENDIX VIII

2018 Fish Length Frequency Plots

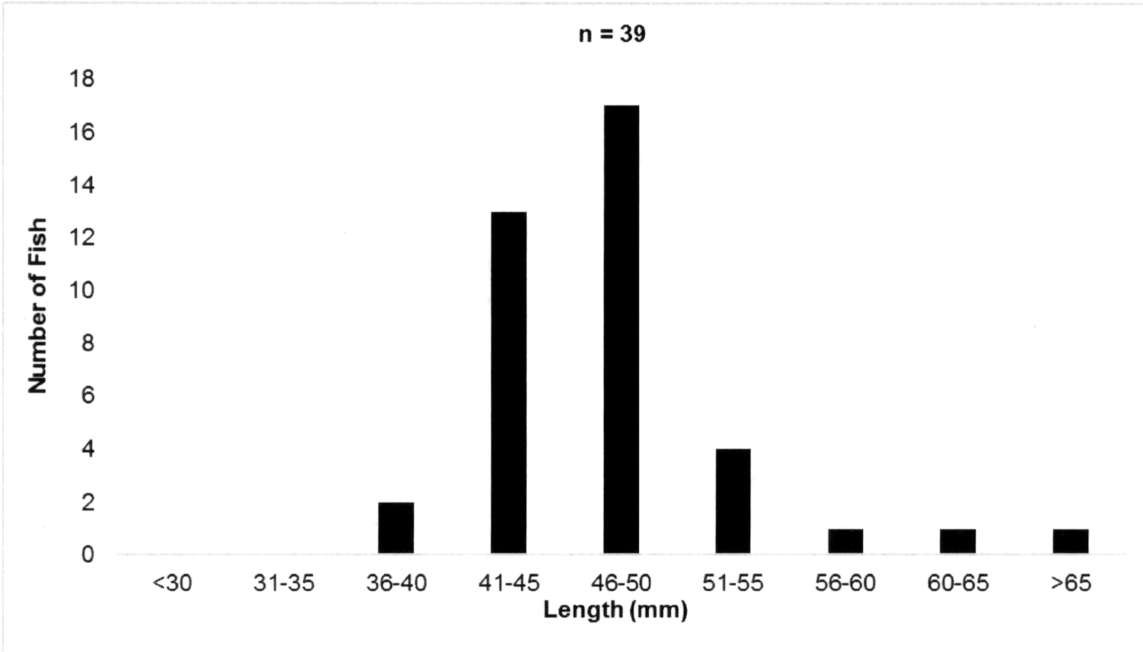


Figure VIII-1: Length Frequency Histogram for Brook Stickleback, Station NNL-1 (Muskeg Lake), Spring 2018

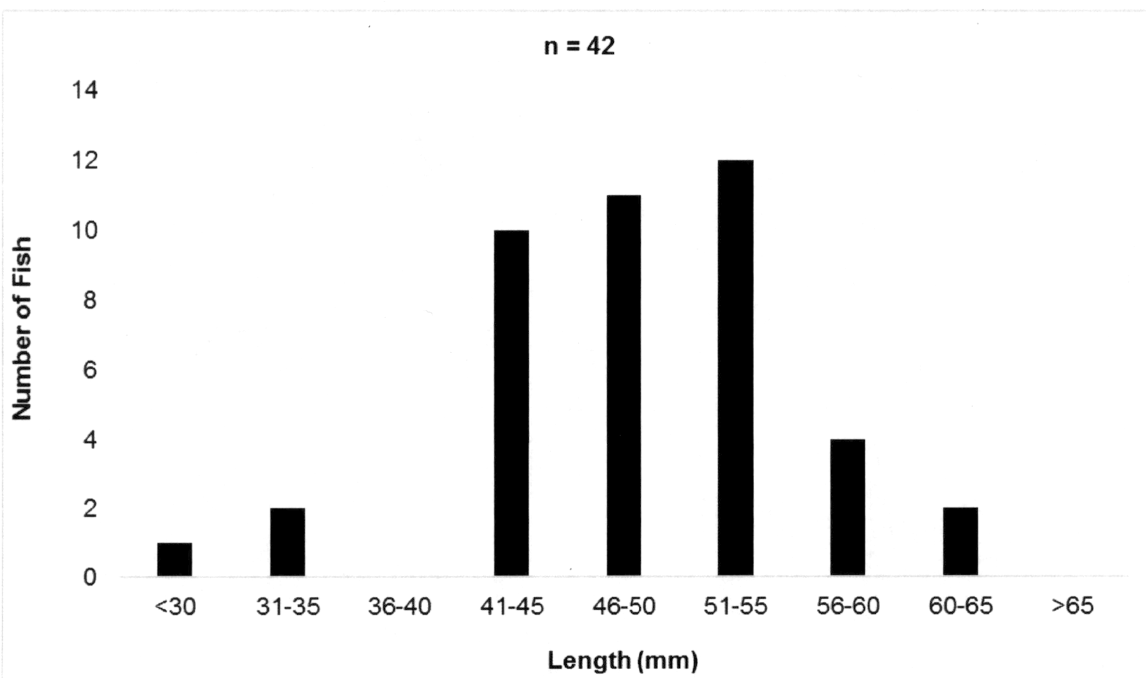


Figure VIII-2: Length Frequency Histogram for Brook Stickleback, Station NNL-1 (Muskeg Lake), Summer 2018

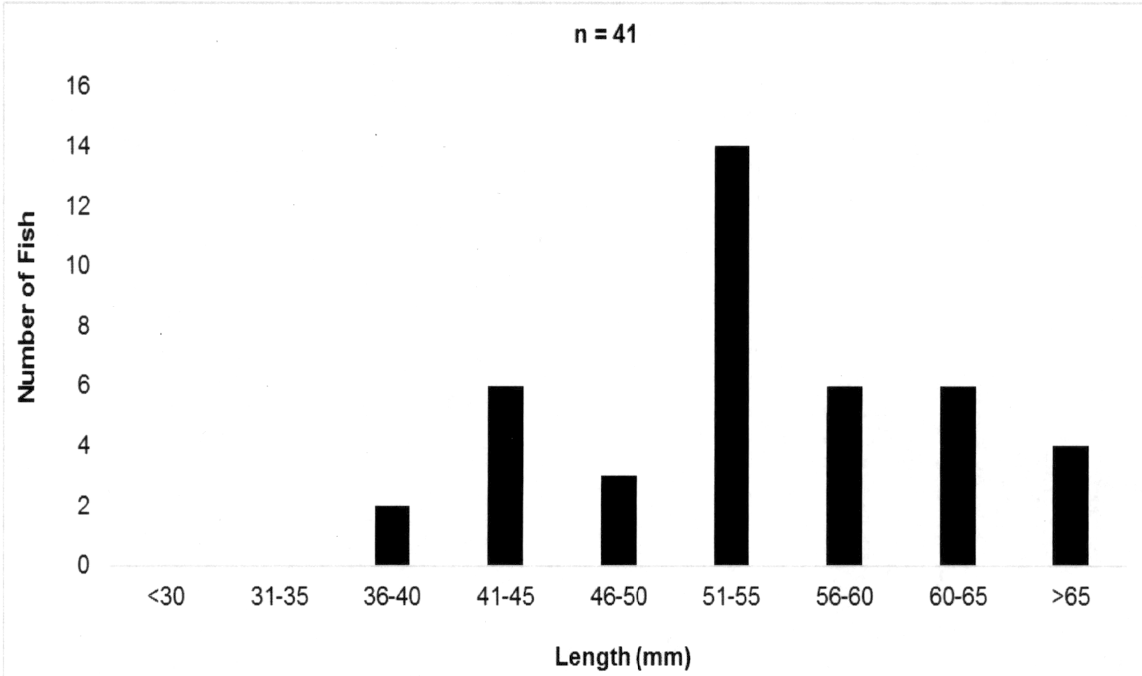


Figure VIII-3: Length Frequency Histogram for Finescale Dace, Station NNL-1 (Muskeg Lake), Spring 2018

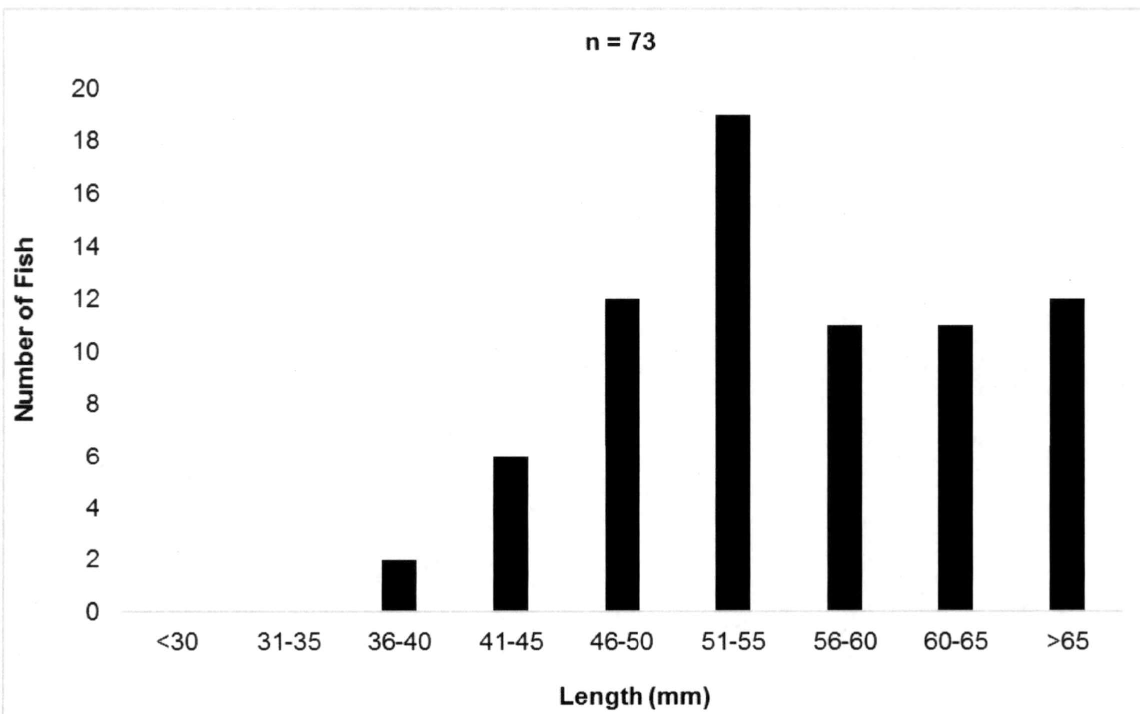


Figure VIII-4: Length Frequency Histogram for Finescale Dace, Station NNL-1 (Muskeg Lake), Summer 2018

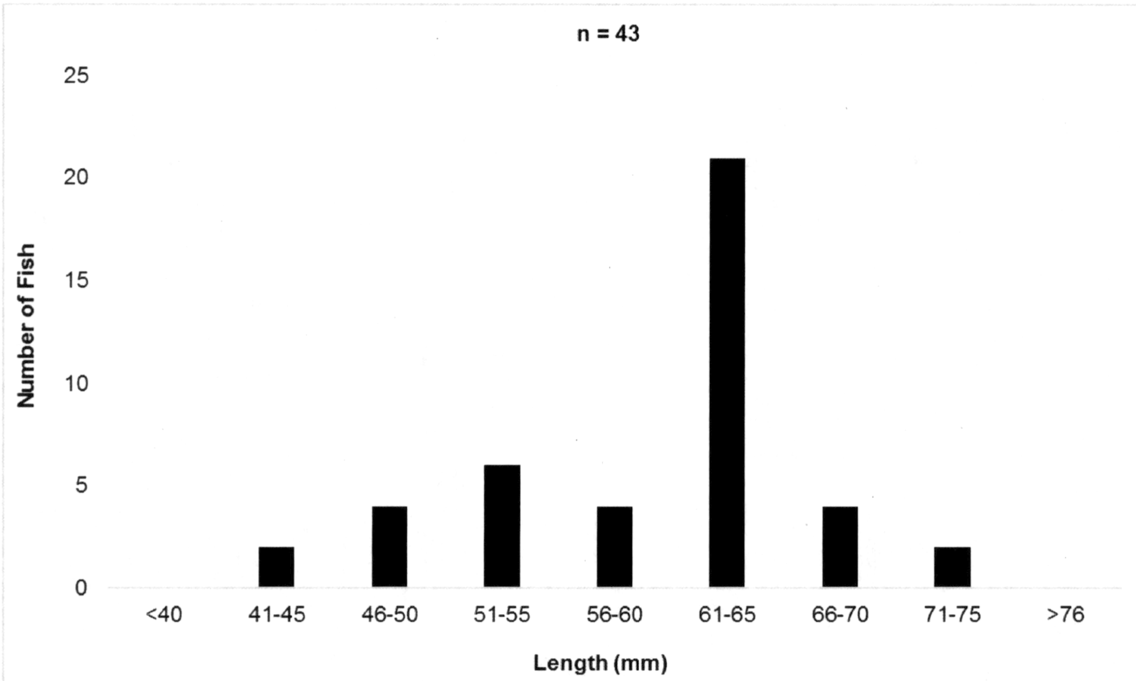


Figure VIII-5: Length Frequency Histogram for Fathead Minnow, Station NNL-1 (Muskeg Lake), Spring 2018

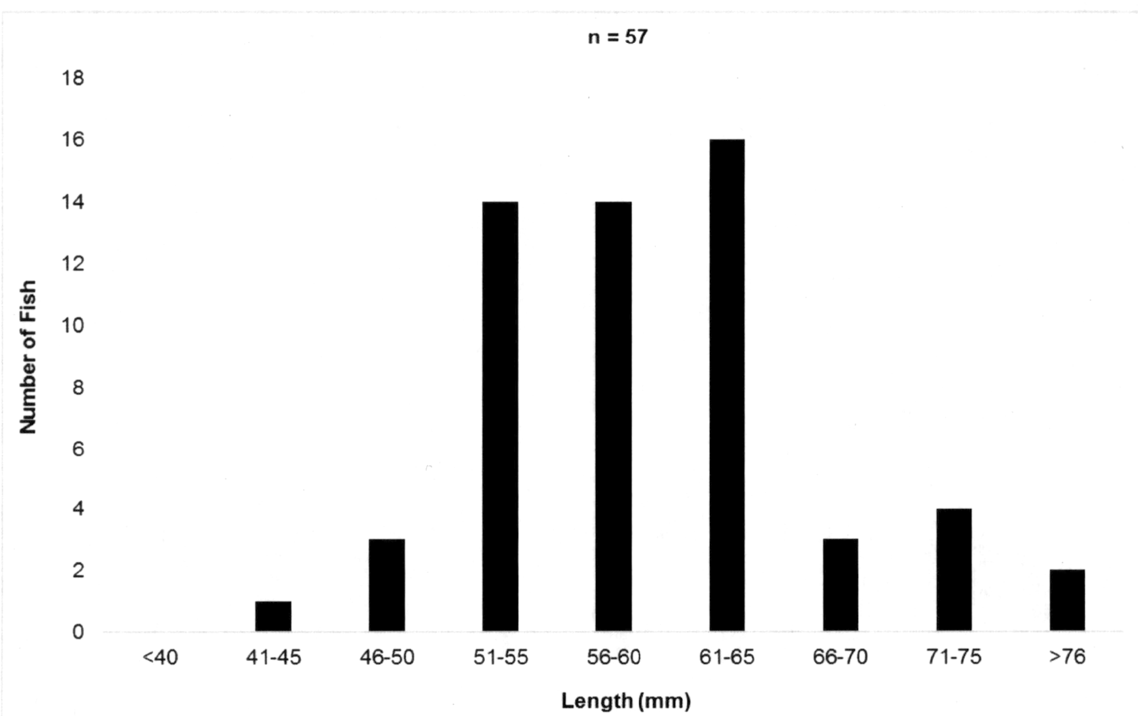


Figure VIII-6: Length Frequency Histogram for Fathead Minnow, Station NNL-1 (Muskeg Lake), Summer 2018

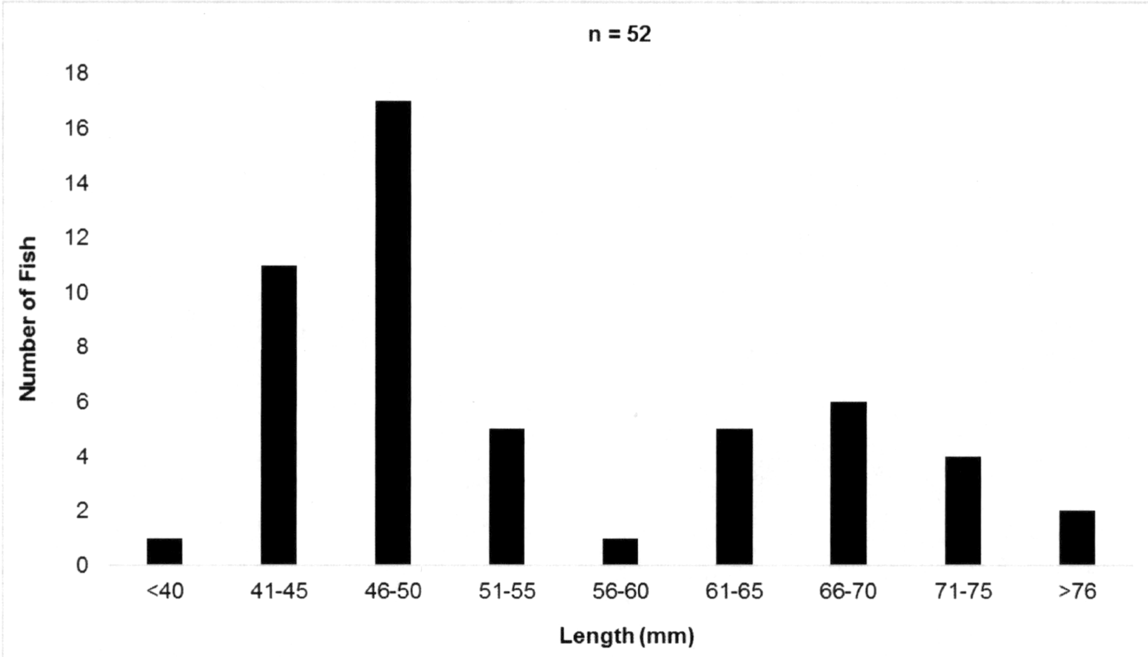


Figure VIII-7: Length Frequency Histogram for Northern Redbelly Dace, Station NNL-1 (Muskeg Lake), Spring 2018

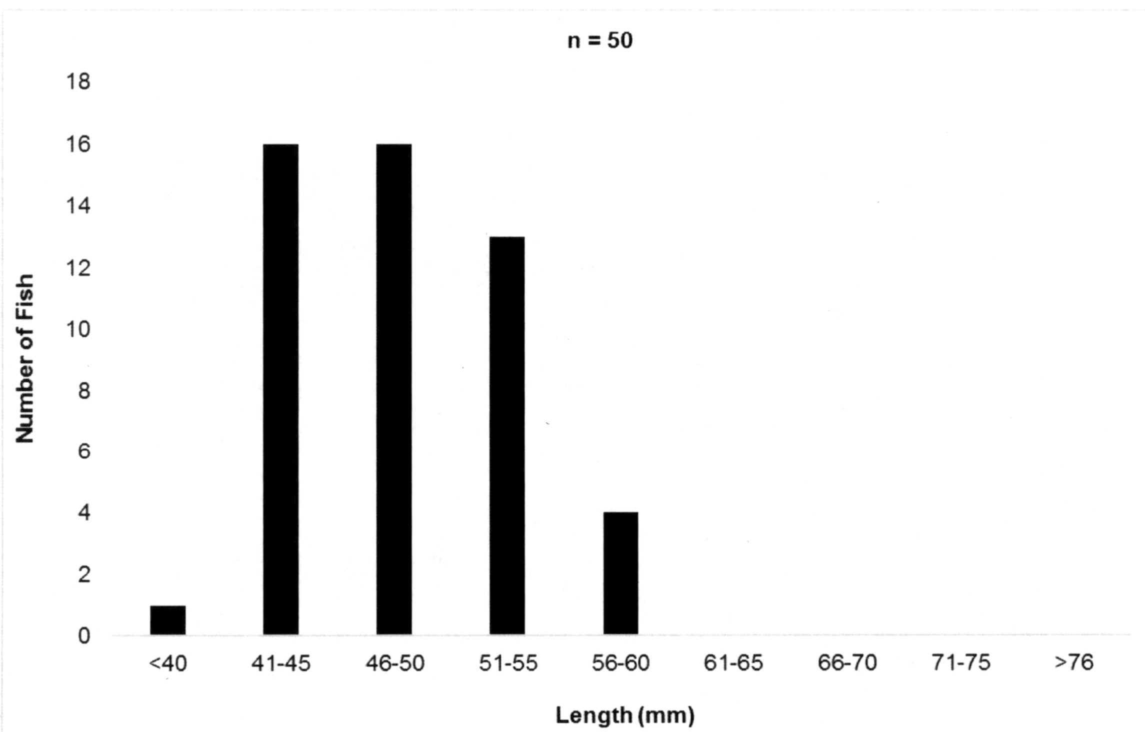


Figure VIII-8: Length Frequency Histogram for Northern Redbelly Dace, Station NNL-1 (Muskeg Lake), Summer 2018

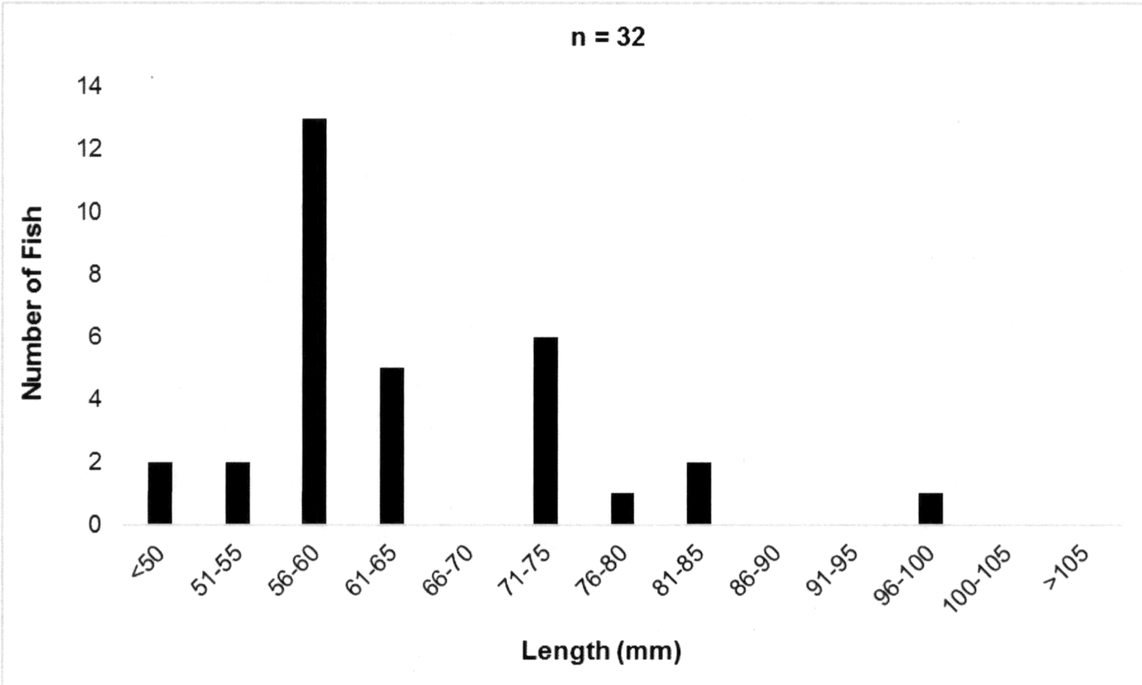


Figure VIII-9: Length Frequency Histogram for Pearl Dace, Station NNL-1 (Muskeg Lake), Spring 2018

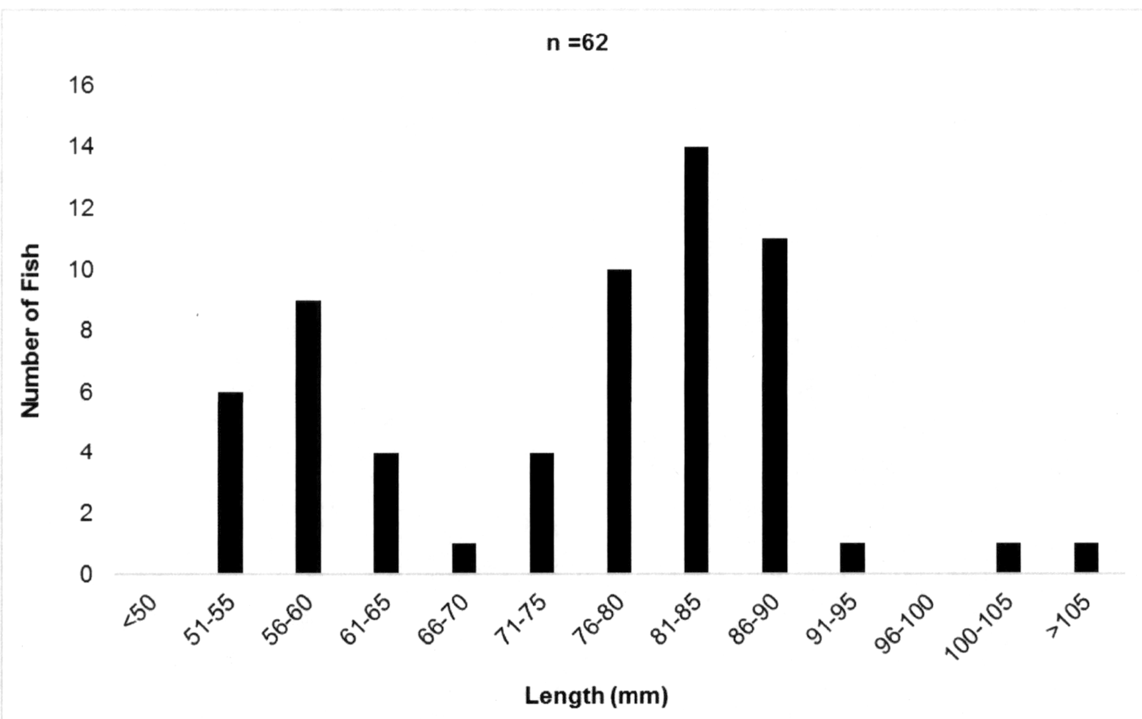


Figure VIII-10: Length Frequency Histogram for Peal Dace, Station NNL-1 (Muskeg Lake), Summer 2018

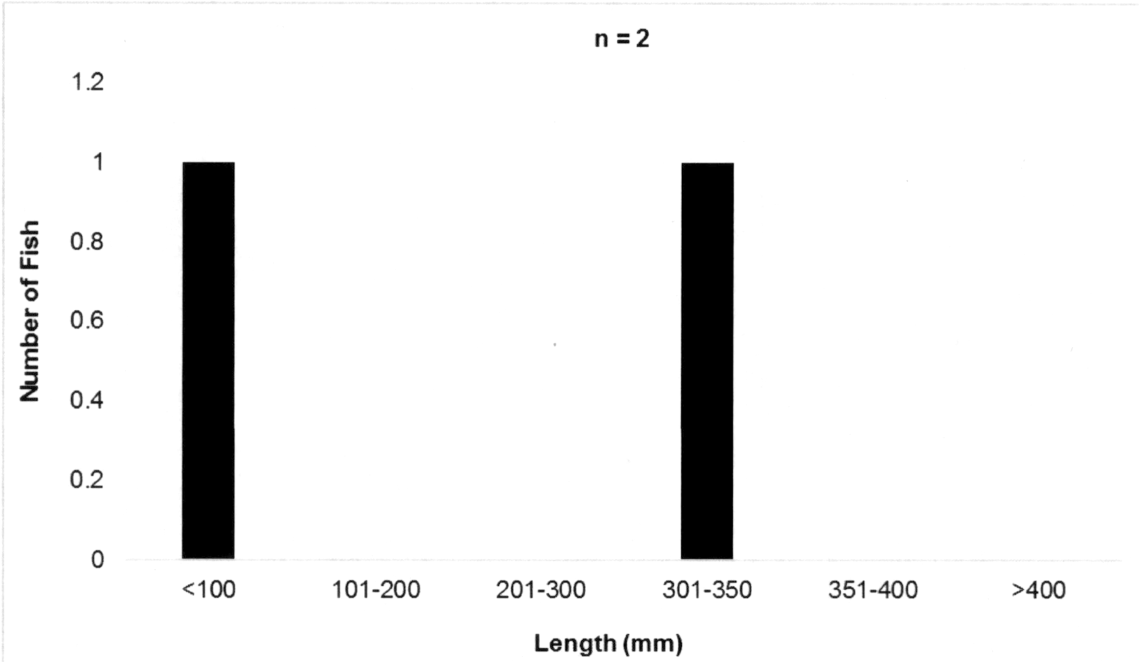


Figure VIII-11: Length Frequency Histogram for Longnose Sucker, Station NNL-1 (Muskeg Lake), Spring 2018

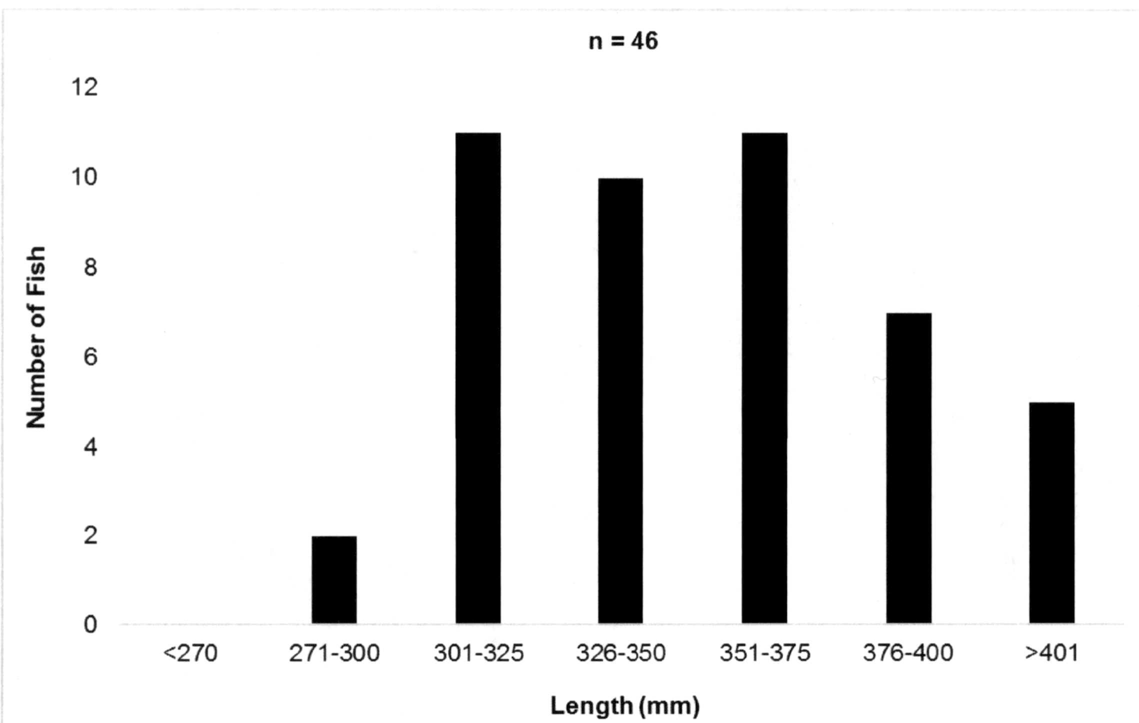


Figure VIII-12: Length Frequency Histogram for White Sucker, Station NNL-1 (Muskeg Lake), Spring 2018

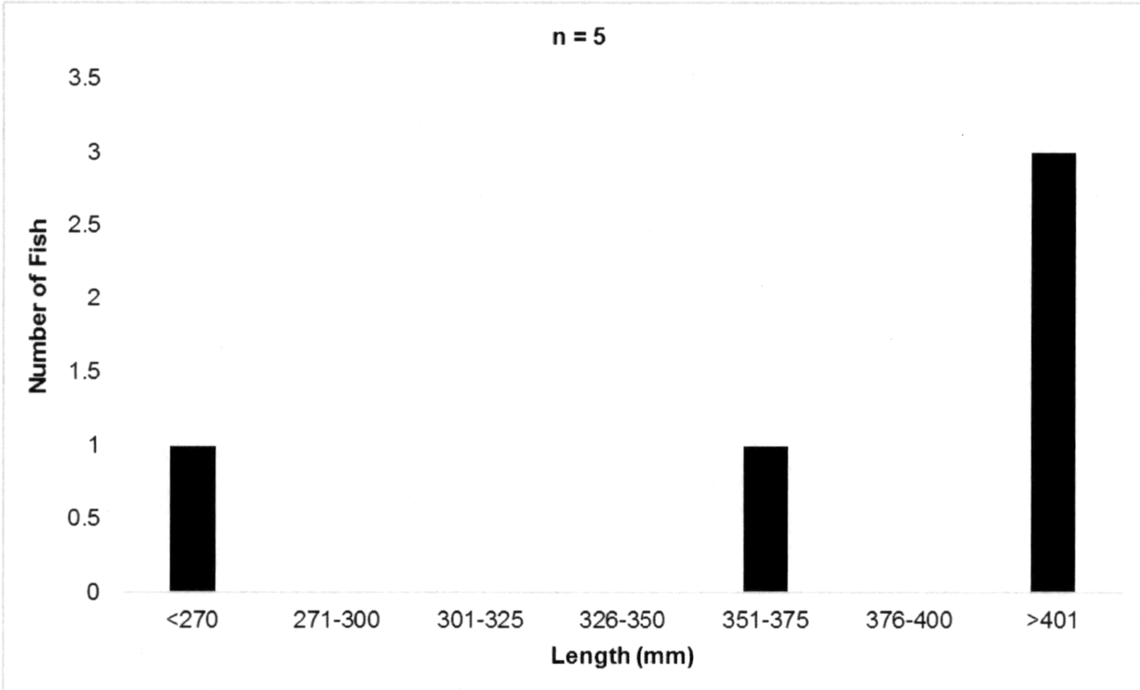


Figure VIII-13: Length Frequency Histogram for White Sucker, Station NNL-1 (Muskeg Lake), Summer 2018

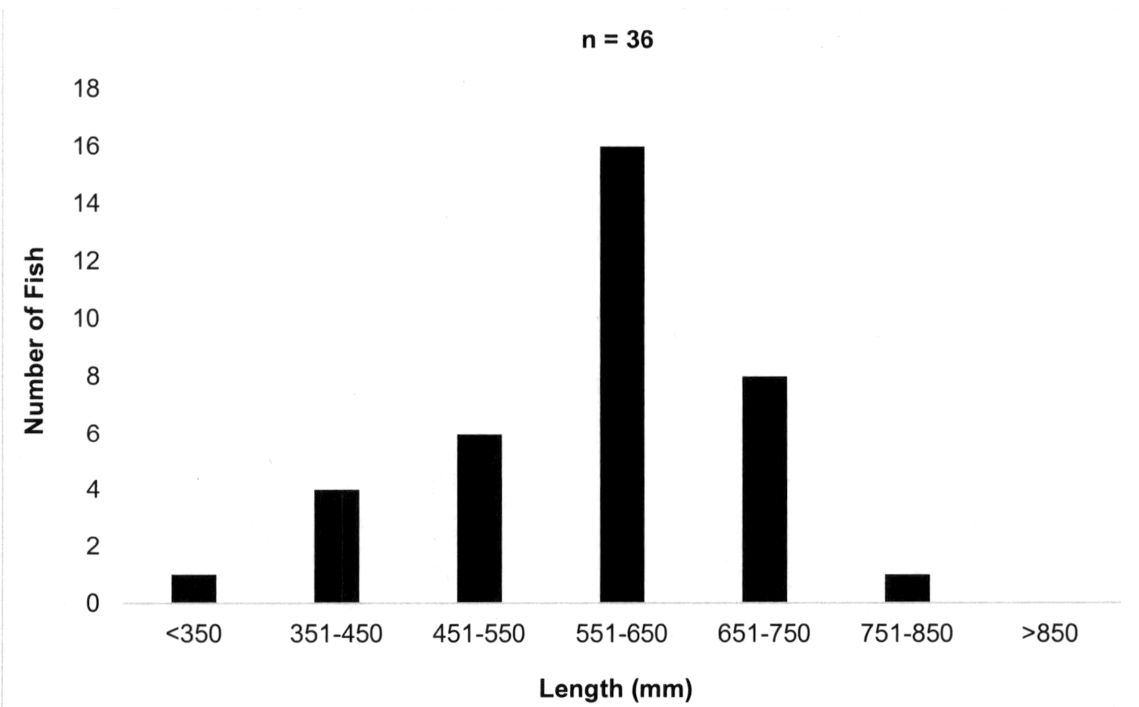


Figure VIII-14: Length Frequency Histogram for Northern Pike, Station NNL-1 (Muskeg Lake), Spring 2018

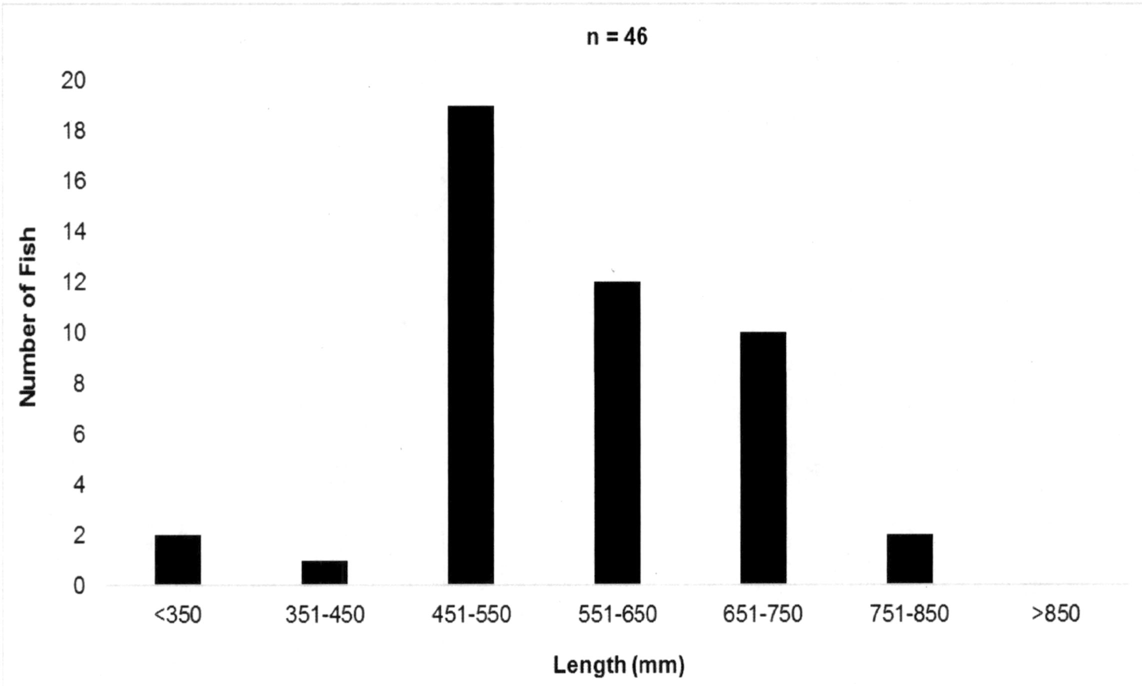


Figure VIII-15: Length Frequency Histogram for Northern Pike, Station NNL-1 (Muskeg Lake), Summer 2018

APPENDIX IX

2018 Fish and Fish Habitat Monitoring Station Photographs



Photo IX-1: View of Littoral Emergent Vegetation in Muskeg Lake, September 2018



Photo IX-2: View of Woody Debris Habitat in Muskeg Lake, May 2018



Photo IX-3: View of Riparian Zone in Muskeg Lake, September 2018



Photo IX-4: View of Muskeg Lake Shoreline, May 2018

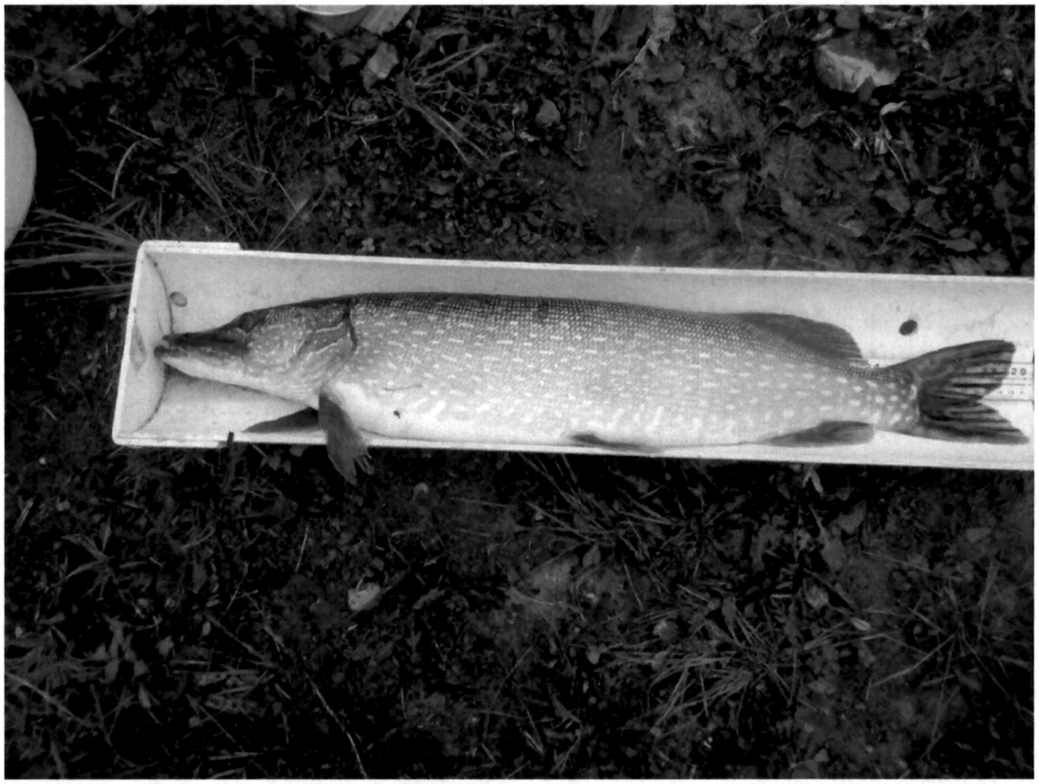


Photo IX-5: Northern Pike Captured by Gill Netting in Muskeg Lake, September 2018

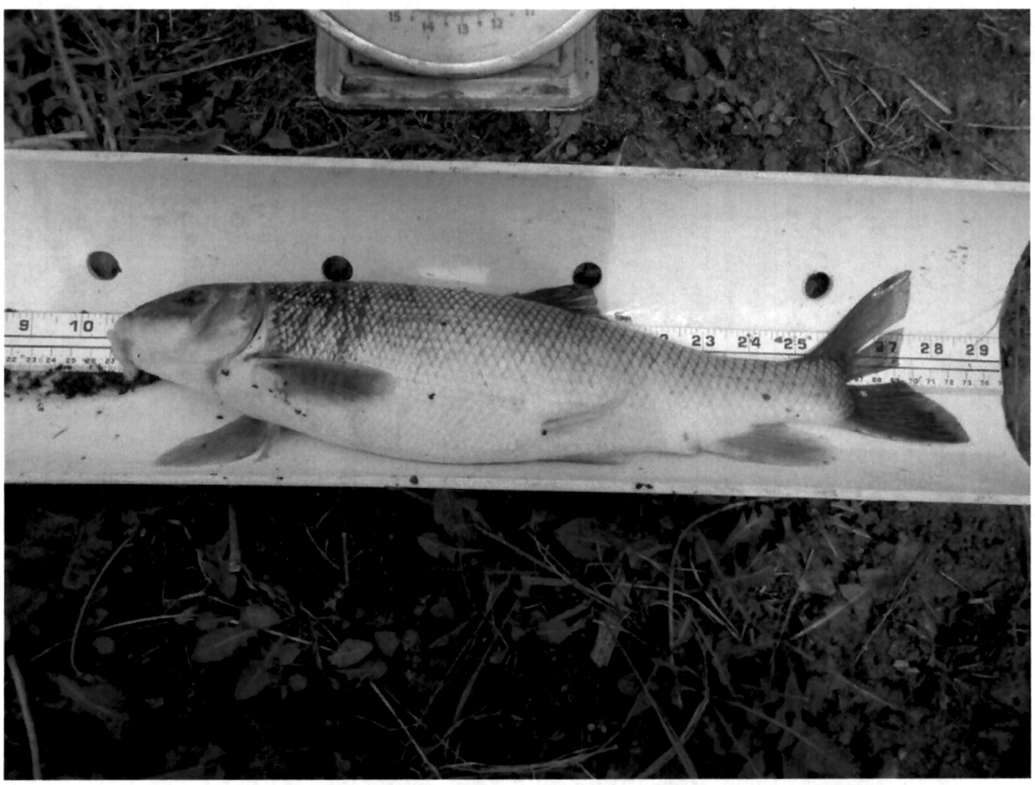


Photo IX-6: White Sucker Captured by Gill Netting in Muskeg Lake, May 2018

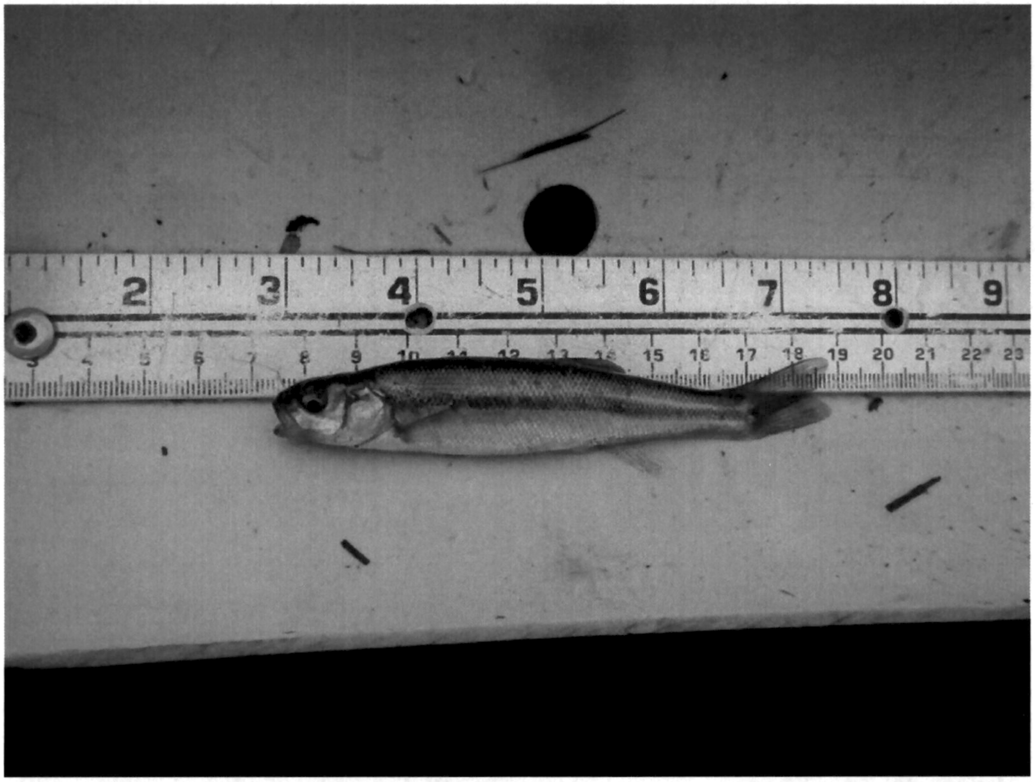


Photo IX-7: Pearl Dace Captured by Minnow Trapping in Muskeg Lake, September 2018



Photo IX-8: View of Connector Channel Facing Kearl Lake, May 2018



Photo IX-9: Large Woody Debris in Muskeg Lake Littoral Zone, May 2018



Photo IX-10: Black Bear in Muskeg Lake Riparian Area

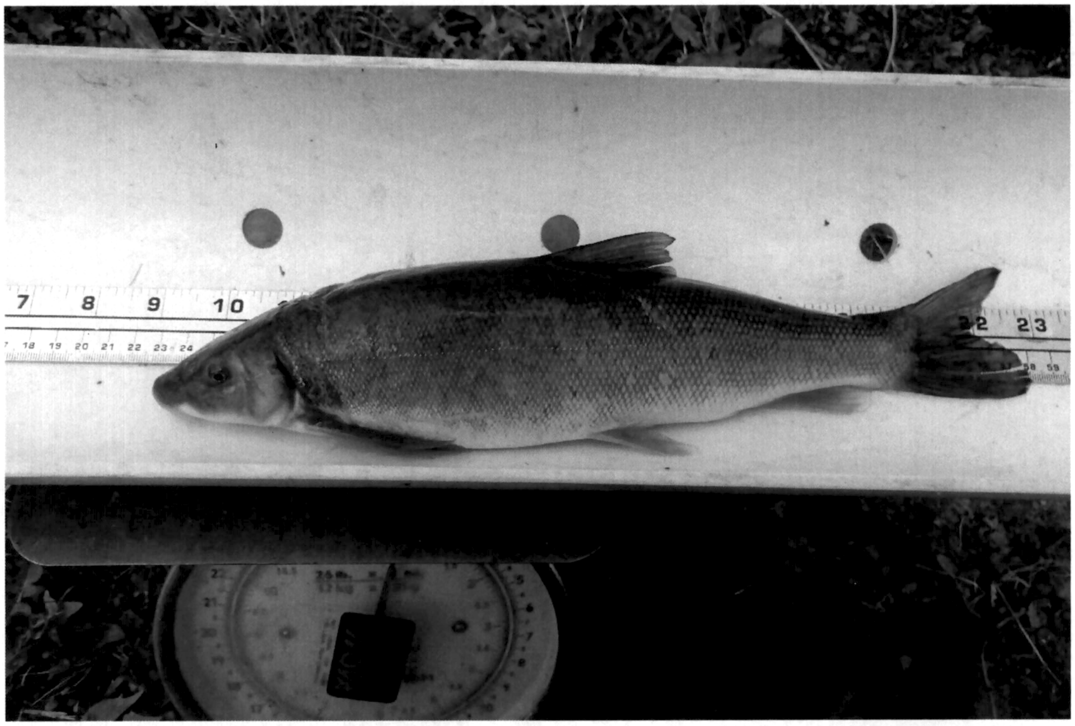


Photo IX-11: Longnose Sucker Captured by Gill Netting in Muskeg Lake, May 2018



Photo IX-12: Submergent Vegetation in Muskeg Lake Littoral Zone, September 2018

APPENDIX X

Muskeg Lake Habitat Suitability Index Modelling Results

Table X-1: List of Abbreviations

Abbreviation	Description	Abbreviation	Description
%	percent	HSI	Habitat Suitability Index
mg/L	milligrams per litre	JTU	Jackson turbidity unit
<	less than	km	kilometre
>	greater than	Log_{10}	Base 10 logarithm
≤	less than or equal to	m	metre
≥	greater than or equal to	m/km	metres/per kilometre
°C	degrees Celsius	m^2, m^3	square metres, cubic metres
cm	centimetre	mm	millimetre
cm/s	centimetre per second	n.a.	not applicable
DO	dissolved oxygen	SI	suitability index

Table X-2: Habitat Data for the Kearl Fish Habitat Compensation Lake Phase I (Muskeg Lake)

Habitat Variable		NNLP Design Specifications and Assumptions[a]	As-Built Specifications and 2016 to 2018 Monitoring Data
Total Surface Area (m^2)		300,000	303,642
Substrate composition (%)		80 sand and silt/clay, 10 gravel and 10 cobble and boulder	80 sand and silt/clay, 10 gravel, 9.7 cobble, 0.3 boulder
Depth percent distribution (%)		0-1 m = 8 >1 to 2 m = 5 >2 to 3 m = 2 >3 to 4 m = 27 >4 to 5 m = 40 >5 to 6 m = 9 >6 to 7 m = 9 Total Littoral (3m or less) = 15% Total Pelagic (>3 m) = 85%	0-1 m = 8.8 >1 to 2 m = 7.3 >2 to 3 m = 7.3 >3 to 4 m = 18.1 >4 to 5 m = 31.4 >5 to 6 m = 18.0 >6 to 7 m = 9.1 Total Littoral (3m or less) = 23.4% Total Pelagic (>3 m) = 76.6%
Maximum depth / Mean depth (m)		7.0 / 4.0	7.0 / 4.0
Littoral cover (%) - average		57	2016 = 10; 2017 = 25; 2018 = 40
Cover types and nesting materials present		Submergent and emergent plants, woody debris/root wads, gravel/cobble	Submergent and emergent plants, woody debris/root wads, gravel/cobble
DO (mg/L)	Summer	7.0 to 14.0 mg/L	2016 = 8.4 to 10.2; 2017 = 4.4 to 9.2; 2018 = 6.3 to 9.3
	Late winter	>2.0 (mid to upper water column)	2016 = 2.9 to 9.7; 2017 = 5.6 to 6.9; 2018 = 3.1 to 6.0
pH	Spring (May / June)	6.0 to 9.0	2016 = 7.5 to 8.6; 2017 = 6.8 to 9.1; 2018 = 7.8 to 8.7
	Summer (July / August)	6.0 to 9.0	2016 = 7.9 to 9.0; 2017 = 7.8 to 8.9; 2018 = 7.9 to 8.9
	Weekly Average	7.0 to 8.0	2016 = 7.8 to 8.9; 2017 = 8.5 to 8.8; 2018 = 8.3 to 8.8
TDS (mg/L)		230 to 245 mg/L	2016 = 174; 2017 = 187; 2018 = 200
Secchi depth (m)		<3.0	2016 = 1.9; 2017 = 0.8; 2018 = 1.9
Temperature (°C) – Spring (Apr to Jun)[b]	Mean	No prediction – not a model variable for the target species	2016 = <17.3; 2017 = <16.7; 2018 = <15.0 (included for Longnose Sucker modelling)
Temperature (°C) – Summer (Jul to Aug)	Mean	19.0 °C	2016 = 19.3; 2017 = 19.3; 2018 = 19.4
	Average Mean weekly	18.0	2016 = 22.2; 2017 = 21.1; 2018 = 19.2
	Peak: July / August	15.0 to 24.0 °C	2016 = 22.7; 2017 = 23.2; 2018 = 22.4
Documented and assumed species		Northern Pike, Yellow Perch, White Sucker, Brook Stickleback, Fathead Minnow, Lake Chub, Pearl Dace	Northern Pike, Yellow Perch, White Sucker, Longnose Sucker, Brook Stickleback, Fathead Minnow, Lake Chub, Northern Redbelly Dace, Pearl Dace

[a] Variable condition used for Habitat Suitability Index modelling in the Kearl No Net Loss Plan (Imperial Oil 2007)

[b] Datasonde record covers only the later portion of the specified period

Table X-3: Habitat Suitability for Brook Stickleback in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having gravel, sand, and clay/silt	90	0.93*	90	0.93*	90	0.93*	0.93*
		Percent area having boulder, bedrock, cobble, and rubble	10		10		10		
V_2	Nesting materials	Algae, submergent plants	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	1.00
		Emergent plants	PRESENT		PRESENT		PRESENT		
		Inundated vegetation							
		Other (e.g., woody debris)	PRESENT		PRESENT		PRESENT		
		None							
V_3	Depth	Percent area having depths up to 2 m	16.1	0.52*	16.1	0.52*	16.1	0.52*	0.52*
		Percent area having depths >2 m to 5 m	56.8		56.8		56.8		
		Percent area having depths >5 m	27.1		27.1		27.1		
V_4	Littoral zone cover	>50%							1.00
		>30 to 50%					YES	0.75	
		>20 to 30%			YES	0.50			
		>0 to 20%	YES	0.25					
		0%							
V_5	Late winter DO	≥1 mg/L	YES	1.00	YES	1.00	YES	1.00	1.00
		<1 mg/L							
V_6	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	1.00
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.25**		**0.50**		**0.52**	**0.52**

* Weighted average of individual suitability index (SI) values for different variable conditions
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

Table X-4: Habitat Suitability for Finescale Dace in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having gravel, sand, and clay/silt	90	0.95*	90	0.95*	90	0.95*	n/m
		Percent area having boulder, cobble and rubble	10		10		10		
		Percent area having bedrock	0		0		0		
V_2	Cover	Submergent and emergent plants, woody debris, inundated vegetation	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	n/m
		Rubble and cobble	PRESENT		PRESENT		PRESENT		
		Boulder and bedrock	PRESENT		PRESENT		PRESENT		
V_3	Depth	Percent area having depths 0 to 2 m	16.1	0.52*	16.1	0.52*	16.1	0.52*	n/m
		Percent area having depths >2 to 5 m	56.8		56.8		56.8		
		Percent area having depths >5 m	27.1		27.1		27.1		
V_4	Littoral zone cover	>50%							n/m
		>30 to 50%					YES	0.75	
		>20 to 30 %			YES	0.50			
		>0 to 20%	YES	0.25					
		0%							
V_5	Late winter DO	≥1 mg/L	YES	1.00	YES	1.00	YES	1.00	n/m
		<1 mg/L							
V_6	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	n/m
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.25**		**0.50**		**0.52**	**n/m**

* Weighted average of individual suitability index (SI) values for different variable conditions; - N/A species was not modelled for in NNL Plan
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007); n/m = not modelled as part of No Net Loss Plan

Table X-5: Habitat Suitability for Fathead Minnow in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having gravel, sand, and clay/silt	90	0.95*	90	0.95*	90	0.95*	0.94*
		Percent area having boulder, cobble and rubble	10		10		10		
		Percent area having bedrock	0		0		0		
V_2	Cover	Submergent and emergent plants	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	1.00
		other (e.g., woody debris, rock)	PRESENT		PRESENT		PRESENT		
V_3	Spawning material	Underside of rocks, logs, debris, broadleaf vegetation	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	1.00
		Vertical surfaces of emergents (stems)	PRESENT		PRESENT		PRESENT		
		No suitable material							
V_4	Depth	Percent area having depths up to 2 m	16.1	0.52*	16.1	0.52*	16.1	0.52*	0.52*
		Percent area having depths >2 to 5 m	56.8		56.8		56.8		
		Percent area having depths >5 m	27.1		27.1		27.1		
V_5	Littoral zone cover (%)	>50%							1.00
		>30 to 50%					YES	0.75	
		>20 to 30%			YES	0.50			
		>0 to 20%	YES	0.25					
		0%							
V_6	Late winter DO (mg/L)	≥1 mg/L	YES	1.00	YES	1.00	YES	1.00	1.00
		<1 mg/L							
V_7	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	1.00
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.25**		**0.50**		**0.52**	**0.52**

* Weighted average of individual suitability index (SI) values for different variable conditions
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

Table X-6: Habitat Suitability for Lake Chub in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having boulder, rubble, cobble, gravel	19.7	0.60*	19.7	0.60*	19.7	0.60*	0.60*
		Percent area having sand, silt/clay, bedrock	80.3		80.3		80.3		
		Percent area having bedrock	0		0		0		
V_2	Cover	Submergent and emergent plants, woody debris, rock	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	1.00
		No cover							
V_3	Depth	Percent area having depths up to 2 m	16.1	0.65*	16.1	0.65*	16.1	0.65*	0.69*
		Percent area having depths >2 to 5 m	56.8		56.8		56.8		
		Percent area having depths >5 m	27.1		27.1		27.1		
V_4	Littoral zone cover	>20 to 50%			YES	1.00	YES	1.00	0.75
		>10 to 20% or >50 to 65%							
		>5 to 10% or >65 to 75%	YES	0.50					
		>0 to 5% or >75%							
		0%							
V_5	Late winter DO	≥2 mg/L	YES	1.00	YES	1.00	YES	1.00	1.00
		1 to 2 mg/L							
		<1 mg/L							
V_6	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	1.00
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.50**		**0.60**		**0.60**	**0.60**

* Weighted average of individual suitability index (SI) values for different variable conditions
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

Table X-7: Habitat Suitability for Northern Redbelly Dace in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having gravel, sand, and clay/silt	90	0.95*	90	0.95*	90	0.95*	n/m
		Percent area having boulder, cobble and rubble	10		10		10		
		Percent area having bedrock	0		0		0		
V_2	Cover	Submergent and emergent plants, woody debris, inundated vegetation	PRESENT	1.00	PRESENT	1.00	PRESENT	1.00	n/m
		Rubble and cobble	PRESENT		PRESENT		PRESENT		
		Boulder and bedrock	PRESENT		PRESENT		PRESENT		
V_3	Depth	Percent area having depths 0 to 2 m	16.1	16.1	16.1	0.52*	16.1	0.52*	n/m
		Percent area having depths >2 to 5 m	56.8	56.8	56.8		56.8		
		Percent area having depths >5 m	27.1	27.1	27.1		27.1		
V_4	Littoral zone cover	>50%							n/m
		>30 to 50%					Yes	0.75	
		>20 to 30 %			Yes	0.50			
		>0 to 20%	YES	0.25					
		0%							
V_5	Late winter DO	≥1 mg/L	YES	1.00	YES	1.00	YES	1.00	n/m
		<1 mg/L							
V_6	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	n/m
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.25**		**0.50**		**0.52**	**n/m**

* Weighted average of individual suitability index (SI) values for different variable conditions
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007); n/m = not modelled as part of No Net Loss Plan

Table X-8: Habitat Suitability for Pearl Dace in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Substrate	Percent area having gravel, sand, clay/silt	90	0.95*	90	0.95*	90	0.95*	0.94*
		Percent area having rubble and cobble	9.7		9.7		9.7		
		Percent area having boulder and bedrock	0.3		0.3		0.3		
V_2	Cover	Submergent and emergent vegetation	PRESENT	1.0	PRESENT	1.0	PRESENT	1.0	1.0
		Rubble and cobble	PRESENT		PRESENT		PRESENT		
		Boulder and bedrock	PRESENT		PRESENT		PRESENT		
V_3	Depth	Percent area having depths 0 to 2 m	16.1	0.52*	16.1	0.52*	16.1	0.52*	0.52*
		Percent area having depths >2 to 5 m	56.8		56.8		56.8		
		Percent area having depths >5 m	27.1		27.1		27.1		
V_4	Littoral zone cover	>20 to 50%			YES	1.00	YES	1.00	0.75
		>10 to 20% or >50 to 65%							
		>5 to 10% or >65 to 75%	YES	0.50					
		0 to 5% or >75 to 100%							
V_5	Late winter DO	≥1 mg/L	YES	1.00	YES	1.00	YES	1.00	1.00
		<1 mg/L							
V_6	pH	6 to 9	YES	1.00	YES	1.00	YES	1.00	1.00
		5.5 to <6							
		<5.5 or >9							
			HSI Value	**0.50**		**0.52**		**0.52**	**0.52**

* Weighted average of individual suitability index (SI) values for different variable conditions
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

Table X-9: Habitat Suitability for Longnose Sucker in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Spawning location	Riffles present with suitable substrate (e.g., bedrock or boulder)		0.50		0.50		0.50	n/m
		Riffles present, but not suitable substrate (e.g., bedrock or boulder) for spawning. No riffles present.	YES		YES		YES		
V_2	Depth of riffle for spawning	Riffles present with suitable substrate (e.g., bedrock or boulder)		0.50		0.50		0.50	n/m
		Riffles present, but not suitable substrate (e.g., bedrock or boulder) for spawning. No riffles present.	YES		YES		YES		
V_3	Current velocity of spawning habitat	Riffles present with suitable substrate (e.g., bedrock or boulder)		0.50		0.50		0.50	n/m
		Riffles present, but not suitable substrate (e.g., bedrock or boulder) for spawning. No riffles present.	YES		YES		YES		
V_4	Mean water temperature (˚C) during spawning and incubation (April 1to June 30)	Refer to SI curve in model*	<17.3[(a)]	0.50	<16.7[(a)]	0.50	<15.0[(a)]	1.00	n/m
V_6	Substrate type	Refer to SI curve in model*	80% gravel, sand, clay/slit, 20% cobble, gravel, boulder	0.50 (assigned)	80% gravel, sand, clay/slit, 20% cobble, gravel, boulder	0.50 (assigned)	80% gravel, sand, clay/slit, 20% cobble, gravel, boulder	0.50 (assigned)	
		If the HSI result is <0.5 due to this variable, SI = 0.5							

Table X-9: Habitat Suitability for Longnose Sucker in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_7	Percent cover (e.g., vegetation, boulders, rubble) in shallow/shoreline areas (May 1 to July 31)	Refer to SI curve in model*	10%	0.60	25%	1.00	40%	1.00	n/m
V_9	Maximum water depth (m)	Refer to SI curve in model*	7 m	0.50	7 m	0.50	7 m	0.50	n/m
V_{10}	Average turbidity (Secchi disk) during the growing season	Assumed not to be limiting	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	n/m
V_{11}	pH range during the summer (July 1 to Aug 31)	Refer to SI curve in model*	7.9 - 9.0	1.00	7.8 - 8.9	1.00	7.9 - 8.9	1.00	n/m
V_{12}	DO (mg/L) range during the summer (July 1 to Aug 31)	Refer to SI curve in model*	8.38 - 10.17	1.00	4.44 - 9.15	0.90	6.28 - 9.31	1.00	n/m
V_{13}	Mean water temperature (˚C) during the summer (July 1 to August 31)	Refer to SI curve in model*	19.3	1.00	19.3	1.00	19.4	1.00	n/m
			HSI Value	**0.61**		**0.69**		**0.78**	**n/m**

(a) datsondes not deployed until later portion of spring period resulting in overestimation of temperature range
*Edwards 1983
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007); n/m = not modelled as pert of No Net loss Plan

Table X-10: Habitat Suitability for White Sucker in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Maximum monthly average turbidity during the year (JTU)	Assume not limiting	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	1.00
V_2	Weekly average pH during the year under stable conditions	Weekly average pH during the year under stable conditions	7.78 - 8.86	0.90	8.47 - 8.82	0.90	8.28 - 8.82	0.90	1.00
		If data are insufficient, SI = 1							
V_3	Minimum DO during May-August in areas of suitable temperature.	Assume not limiting	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	Assign 1.00	1.00 (assigned)	1.00
V_4	Average of mean weekly water temperature July 1 to August 31 for adults and juveniles	Refer to SI curve in model*	19.1	1.00	19.1	1.00	19.2	1.00	0.90
V_5	Average of mean weekly water temperature July 1 to August 31 for fry	Refer to SI curve in model*	22.2	0.95	21.1	0.90	19.2	0.75	0.80
V_6	Average of mean weekly water temperatures during spawning and incubation (April 1 to June 30)	Refer to SI curve in model*	<17.3[(a)]	0.70	<16.7[(a)]	0.75	<15.0[(a)]	1.00	1.00
V_{11}	Littoral spawning substrate	Refer to SI curve in model*	Littoral spawning substrate gravel-cobble, remaining littoral sand-silt	0.61	Littoral spawning substrate gravel-cobble, remaining littoral sand-silt	0.61	Littoral spawning substrate gravel-cobble, remaining littoral sand-silt	0.61	0.61
		HSI Value		**0.74**		**0.74**		**0.74**	**0.74**

(a) datsondes not deployed until later portion of spring period resulting in overestimation of temperature range
* - Twomey and Nelson 1984
Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

Table X-11: Habitat Suitability for Northern Pike in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Ratio of spawning habitat area to summer habitat area (estimated proportion of the area that would be less than 1 m deep during spring and with aquatic vegetation or debris)	Refer to SI curve in model*	Proportion 0.088	0.16	Proportion 0.088	0.16	Proportion 0.088	0.40	0.60
V_2	Drop in water level (m) during embryo and fry stages (period of spawning through the end of June)	Refer to SI curve in model*	Stable water level	1.00	Stable water level	1.00	Stable water level	1.00	0.90
V_3	Percent of midsummer area with emergent or submergent aquatic vegetation	Refer to SI curve in model*	2.3	0.21	5.9	0.40	6.4	0.42	0.50
V_4	Log_{10} of total dissolved solids concentration in surface waters during midsummer	Refer to SI curve in model*	2.24	1.00	2.27	1.00	2.30	1.00	1.00
V_5	Least suitable pH in spawning habitat during embryo and fry stages (May 1 to June 30)	Refer to SI curve in model*	7.5-8.6[a]	1.00	6.8-9.1[a]	1.00	7.8-8.7[a]	1.00	1.00
V_6	Average length of frost-free season (days)	Refer to SI curve in model*	94 days**	0.83	94 days**	0.83	94 days**	0.83	0.83[b]
V_7	Maximal weekly average temperature of surface waters (average of the 7-day peak temperatures during that warmest period of the year)	Refer to SI curve in model*	22.7	1.00	23.2[a]	1.00	>22.4	1.00[c]	1.00
V_{10}	Late winter DO	≥2 mg/L	YES	1.00	YES	1.00	YES	1.00	1.00
		<2 mg/L							
			HSI Value	**0.16**		**0.16**		**0.40**	**0.50**

[a] datasondes not deployed for the full length of the specified period; [b] pelagic datasonde record only - likely warmer temps in littoral; [c] Original value in NNLP was 0.70 – adjusted to 0.83 based on more recent regional information from Alberta Agriculture

* - Inskip 1982

** - Alberta Agriculture 2017

Note: NNLP = Kearl No Net Loss Plan (Imperial Oil 2007)

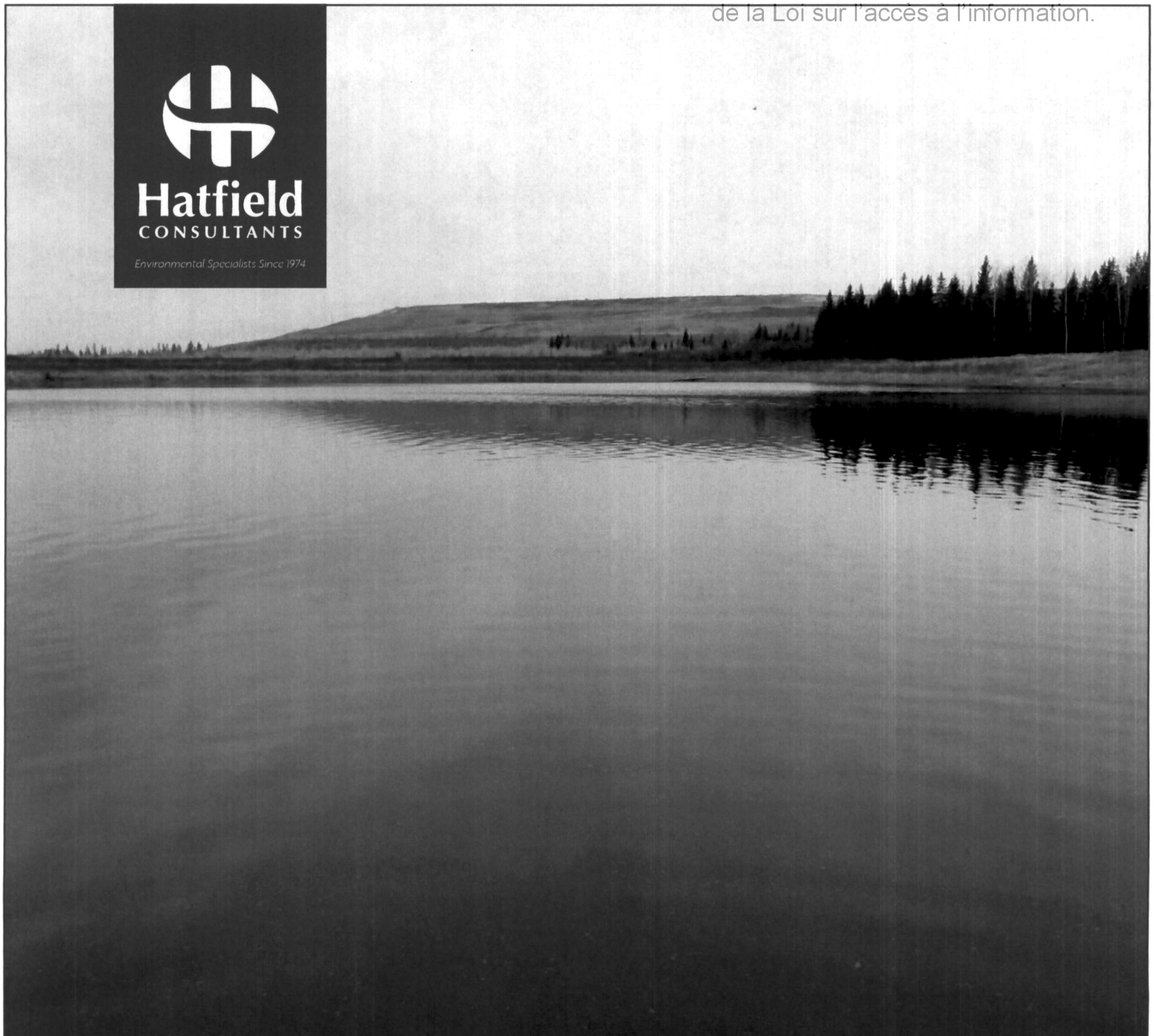
Table X-12: Habitat Suitability for Yellow Perch in Muskeg Lake, 2016 to 2018

Model Variable	Variable Description	Category	2016 Input Data Used	2016 Suitability Index (SI)	2017 Input Data Used	2017 Suitability Index (SI)	2018 Input Data Used	2018 Suitability Index (SI)	NNLP Predicted Suitability Index (SI)
V_1	Percent littoral area during summer	Refer to SI curve in model*	23.4	1.00	23.4	1.00	23.4	1.00	0.90
V_3	Percent cover during summer within littoral areas	Refer to SI curve in model*	10	0.50	25	1.00	40	1.00	0.80
V_4	Most suitable water temperatures within the water column during midsummer for adult, juvenile, fry (July 15 - Aug 15)	Refer to SI curve in model*	20.6 - 23.8	0.96	19.5 - 23.9	0.93	18.2-22.9	0.90	0.90
V_5	Most suitable water temperatures within littoral areas during spawning and embryo development (May 1 - June 30)	Refer to SI curve in model*	<18.2 - 23.9[a]	0.10	<15.5 - 20.9[a]	0.10	<13.7 - 17.7[a]	0.30	1.00
V_6	Minimum dissolved oxygen level at the two locations selected for the most suitable temperatures for variables V_4 and V_5	Refer to SI curve in model*	7.25	1.00	3.87	0.80	4.93	0.98	1.00
V_7	Degree-days between 4 and 10 from Oct 30 to April 1	Refer to SI curve in model*	Assign 1.00 not relevant	1.00 (assigned)	Assign 1.00 not relevant	1.00 (assigned)	Assign 1.00 not relevant	1.00 (assigned)	1.00
V_8	pH range during the year	Refer to SI curve in model*	Assign 1.00 not limiting	1.00 (assigned)	Assign 1.00 not limiting	1.00 (assigned)	Assign 1.00 not limiting	1.00 (assigned)	1.00
V_9	Trophic status of lake or lake section	Refer to SI curve in model*	Oligotrophic	0.60	Mesotrophic	1.00	Mesotrophic	1.00	0.70
V_{10}	Late winter DO	≥3 mg/L	YES	1.0	YES	1.0	YES	1.0	1.00
		>1 and <3 mg/L							
		<1 mg/L							
			HSI Value	0.10[b]		0.10[b]		0.30[b]	0.70

[a] datsondes not deployed until later portion of spring period resulting in overestimation of temperature range
[b] Predicted HSI, species not currently present in Muskeg Lake
* Krieger et al. 1983

GOLDER

golder.com



Jackpine Lake Long-term Monitoring Program, 2017 Report

April 2018

Prepared for:
Canadian Natural Upgrading Limited
Fort McMurray, Alberta

#200 - 850 Harbourside Drive, North Vancouver, British Columbia, Canada V7P 0A3 • **Tel: 1.604.926.3261** • Fax: 1.604.926.5389 • **www.hatfieldgroup.com**

Hatfield
CONSULTANTS

JACKPINE LAKE LONG-TERM MONITORING PROGRAM, 2017 REPORT

Prepared for:

CANADIAN NATURAL UPGRADING LIMITED
P.O. BOX 5670
FORT MCMURRAY, AB
CANADA T9H 4W1

Prepared by:

HATFIELD CONSULTANTS
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3

APRIL 2018

SHELL8642
VERSION 2.0

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AESRD	Alberta Environment and Sustainable Resource Development
AER	Alberta Energy Regulator
CCME	Canadian Council for Ministers of the Environment
CEMA	Cumulative Environmental Management Association
CPUE	Catch per unit effort
DFO	Fisheries and Oceans Canada
FWI	Field Work Instructions (Hatfield)
HADD	Harmful Alteration, Disruption or Destruction of Fish Habitat
HI	Hazard Index
HQ	Hazard Quotient
ISQG	Interim Sediment Quality Guidelines
JOSMP	Joint Oil Sands Monitoring Plan
JPM1	Jackpine Mine Phase 1
K_{ow}	Octanol Water Partition Coefficient
MOE	Ministry of Environment
NAPL	Non-Aqueous Phase Liquid
PAH	Polycyclic Aromatic Hydrocarbons
PHC	Petroleum Hydrocarbons
PIT	Passive Integrated Transponder
QA/QC	Quality Assurance and Quality Control
RAMP	Regional Aquatics Monitoring Program
RPD	Relative Percent Difference
SOP	Standard Operating Procedure (Hatfield)
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency

ACKNOWLEDGEMENTS

Project management duties for the 2017 Jackpine Lake Long-term Monitoring Program were fulfilled by Dr. Benjamin Beall, with Daniel Moats acting as Program Director. Contributions to the data analysis and reporting components were made by Mr. Daniel Moats, Dr. Benjamin Beall, Ms. Kaitlyn Roberts, and Mr. Seumas McGrath.

EXECUTIVE SUMMARY

The Jackpine Lake Long-Term Monitoring Program measured key indicators of environmental quality in 2016 and 2017 to track the status and development of the lake ecosystem. The 2017 program focused on the environmental quality of sediments; and the bioaccumulation of mercury in the piscivorous northern pike (*Esox lucius*) population.

The methods and approach used 2017 were consistent with accepted environmental monitoring techniques and previous studies in Jackpine Lake. Sediment quality was evaluated for a range of physico-chemical characteristics, including analytes with established environmental quality guidelines such as metals and polyaromatic hydrocarbons (PAH). The toxicity of sediments was assessed using controlled toxicity assays with cultured invertebrates. The bioaccumulation of mercury in northern pike was measured from non-lethally sampled muscle tissue plugs, with supporting data collected on fish morphology and age determination. The program was designed to collect sufficient individuals to assess tissue mercury concentrations, while the supporting morphology and age data provides information on changes in the northern pike population since Jackpine Lake was commissioned in 2010.

The sampling and analysis components of the 2017 assessment adhered to standard operating procedures and no quality issues were noted, except for the erroneous measurement of total methyl-mercury instead of total mercury in pike tissues. Studies have shown approximately 100% of the mercury in pike and other piscovorous fish is in the form of methyl-mercury (Bloom 1992, Duffy et al 1999, Jackson 1990, Jewett et al 2003, Lasorsa and Allen-Gill 1995). The high correspondence between tissue total mercury and total methyl-mercury concentrations in other studies support the direct comparison of the 2017 tissue mercury data to the earlier results in the program. However, some uncertainty remains because of the potential underestimation of tissue total mercury concentrations.

Sediment quality indicators, including the concentrations of metals and PAH, were generally less than the most conservative environmental quality guidelines for the protection of aquatic life. The sediments in Jackpine Lake continue to accumulate finer particles and organic matter, which may be associated with the observations of increased metal concentrations. In contrast, the concentrations of hydrocarbons and PAH in sediments did not vary substantially relative to previous monitoring programs in Jackpine Lake. The results of the toxicity assays were consistent with the physico-chemical characterization of the sediments. Jackpine Lake sediments did not affect the survival of aquatic invertebrates in controlled assay conditions; however, some effects to the growth rate were observed in sediment samples from the southern basin of the Lake in 2017.

Although the 2017 program was focused on pike larger than 150 mm, fish across a range of ages and sizes continue to be captured in the mercury tissue monitoring program. Fish condition metrics (i.e., Fulton's K and relative weight) indicate that the growth and development of pike in Jackpine Lake has remained consistent since the beginning of the program. The majority of fish sampled in 2017 had tissue mercury concentrations less than the Health Canada guideline for subsistence fishers, and average concentrations appear to have been decreasing since 2014. As expected, older fish have higher tissue mercury concentrations; however, younger fish appeared to be accumulating less mercury in 2016 and 2017 relative to the period of 2011 to 2014.

DISTRIBUTION LIST

The following individuals/firms have received this document:

Name	Firm	Hardcopies	CDs	Email	FTP
Mr. Darryl Chudobiak	CNRL	-	-	✓	-

AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Jackpine Lake Monitoring Program – 2017 - Draft	20180329	Daniel Moats Project Director	Benjamin Beall Project Manager
2	Second version of Jackpine Lake Monitoring Program – 2017	20180412	Daniel Moats Project Director	Benjamin Beall Project Manager

1.0 INTRODUCTION

1.1 OBJECTIVES

The purpose of the Jackpine Lake Long-Term Monitoring Program (the Program) is to characterize and assess key indicators of aquatic health in Jackpine Lake. The 2017 Program focused on two key indicators: (1) environmental quality of sediment; and (2) bioaccumulation of mercury and health of higher aquatic trophic levels. The two assessments were comprised of the following components:

- Sediment sampling to describe environmental quality using physico-chemical analysis and toxicity screening; and
- Collection of northern pike (*Esox lucius*) tissue samples for mercury analysis and supporting measurements of fish condition and age.

1.2 BACKGROUND

In February 2004, the Energy and Utilities Board and Government of Canada Joint Review Panel approved the Shell Canada Energy (Shell) Application for development of the Alberta Oil Sands Project (AOSP) and associated infrastructure. These project components, together known as the Jackpine Mine Project (the Project), are located approximately 70 kilometres north of Fort McMurray and 10 kilometres east of Fort McKay. In 2017, Canadian Natural Upgrading Limited (Canadian Natural) acquired the AOSP from Shell, including the Project. As part of the regulatory approval of the Project, Fisheries and Oceans Canada (DFO) provided an Authorization (No. AB01–743–1) for the harmful alteration, disruption, or destruction of fish habitat (HADD). The Authorization stipulated that monitoring must be undertaken for five years to determine if permanent fish habitat gains at the prescribed compensation ratio have been achieved, to the satisfaction of DFO. The Alberta Energy Regulator (AER) also required Shell to monitor the compensation habitat to ensure it supports a sustainable fishery, as outlined in the Environmental Protection and Enhancement Act Approval (EPEA 153125-00-00).

The first six years of the Program (2010-2015) followed a phased approach, initially sampling physical and chemical habitat variables, followed by the incorporation of lower trophic levels of aquatic organisms, and finally higher trophic levels. A detailed discussion on the design and rationale of the Program is presented in the Shell document titled "*Evaluating Aquatic Losses and Compensation Offsets in the Athabasca Oil Sands*" (Hatfield 2010).

Data collected over the first six years of monitoring have shown that the ecological progression of Jackpine Lake has and continues to occur. The biological colonization by multiple trophic levels, including piscivorous fish, indicates that the physical and chemical characteristics of the lake are suitable to sustain a fully-functioning and ecologically-diverse lake ecosystem.

Historically, the two primary objectives of the Jackpine Lake monitoring program were to: (1) confirm fish populations are established at an acceptable rate and the lake is ecologically self-sustainable; and (2) collect the data that are required to calculate habitat unit offsets for the ten focal fish species. These objectives largely have been fulfilled by utilizing scientifically defensible sampling methods to:

- Quantify habitat gains and fish abundance, to confirm that the amount of habitat created will offset Project-related losses;
- Track trophic status, to ensure Jackpine Lake continues to progress towards an ecologically self-sustaining lake at an acceptable rate; and
- Provide appropriate information to inform adaptive management decisions with respect to future monitoring plans.

At the December 3rd, 2015 meeting with DFO, Shell presented a proposed Long-Term Monitoring Program for Jackpine Lake. This proposal recognized that Jackpine Lake is ecologically and physically stable, based on six years of intensive monitoring during its development. Moreover, the habitat features and habitat units proposed in the 2010 Jackpine Lake No Net Loss Plan have been achieved or exceeded. The Long-Term Monitoring Program recognizes that many parameters of the original monitoring program are no longer required or do not require the same sampling frequency, and it was proposed that most parameters be sampled on a 3-5 year schedule. In contracts, Shell (now Canadian Natural) committed to continue annual sampling of those parameters that approached or exceeded guidelines and/or where the potential for impacts are still unclear (i.e., sediment toxicity, sediment chemistry, and fish tissue total mercury content). Although fisheries population information is an important indicator for Jackpine Lake, the current monitoring program design requires revision to provide a more representative sample for all species, particularly forage fish. This last requirement will be the subject of a future monitoring design.

1.3 STUDY AREA OVERVIEW

Construction of Jackpine Lake began in the winter of 2008/09, consisting of clearing and ditching to dewater the muskeg located within the lake footprint, with infilling occurring between March 27 and April 26, 2010. The lake is positioned in the Muskeg Creek watershed, with the northern basin replacing approximately 300 m of the downstream end of the original Muskeg Creek channel. The most downstream 100 m of Muskeg Creek remains, and as expected, this reach contains flow only during moderate or higher flood conditions. Muskeg Creek now flows into the northeast end of the lake, while the lake outlet is located at the southwest end of the lake and joins Muskeg Creek with Muskeg River (Figure 1.1 and Figure 1.2). The lake is comprised of three distinct areas: a north basin, a shallow interconnecting narrows, and a larger, deeper south basin. The lake has a total surface area of 47.3 ha, of which 27% is < 2 m in depth, 28% is between 2 m and 5 m, and 45% is > 5 m. The lake has a mean depth of 5.1 m, with maximum depths of approximately 7 m and 11 m in the north and south basins, respectively.

Jackpine Lake was designed to support year-round fish populations and to maintain fish passage between Muskeg River and Muskeg Creek. Habitat enhancements were engineered to increase fish productivity throughout the lake, including large organic debris structures cabled to the lake bottom, boulder placements, planting of littoral zone aquatic vegetation, and positioning of cobble and gravel substrates near the lake inlet.

Figure 1.1 **Aerial photograph of Jackpine Lake and the pre- and post-construction locations of lower Muskeg Creek.**

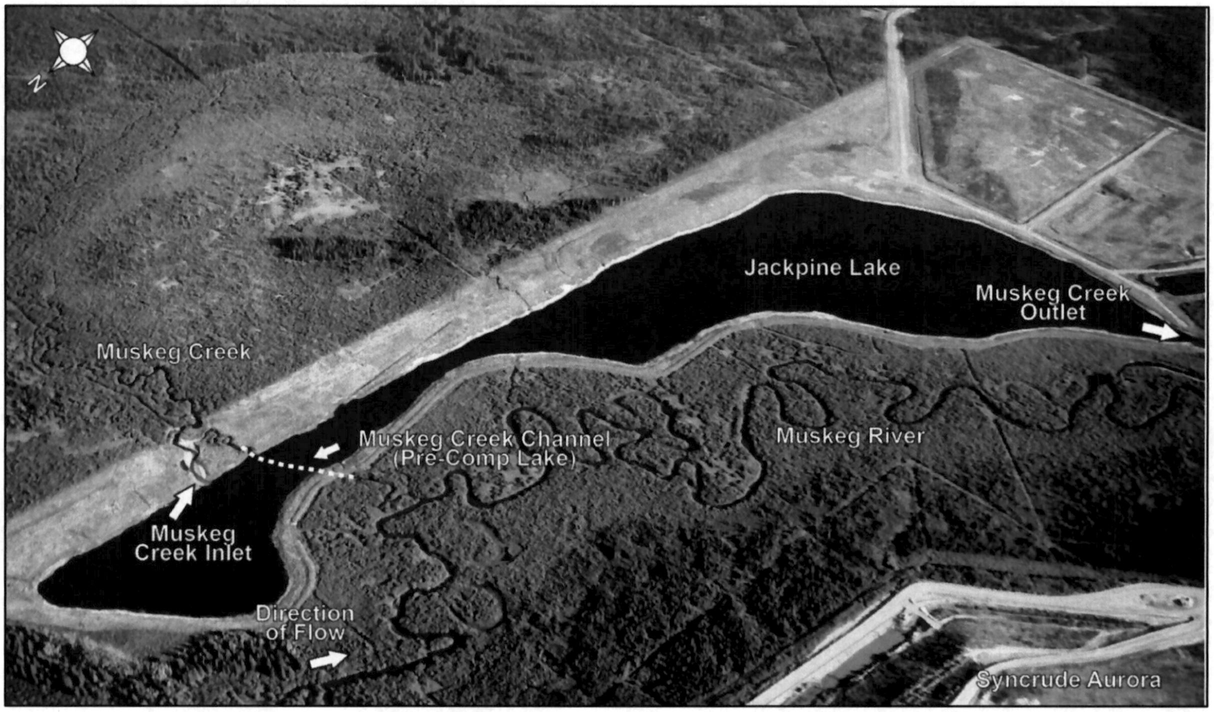
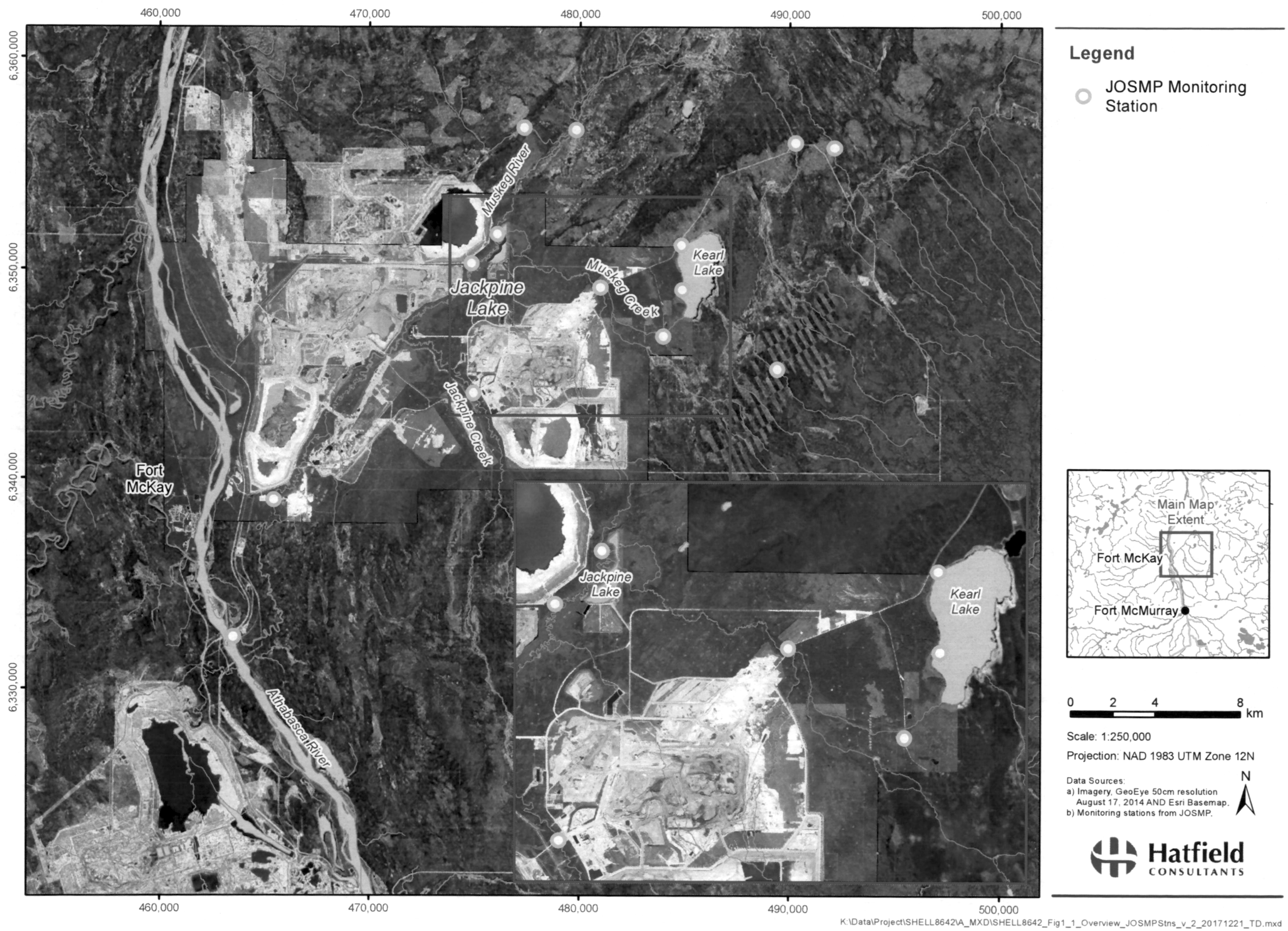


Figure 1.2 Location of Jackpine Lake and JOSMP monitoring stations in the Muskeg River basin.



2.0 METHODS

The key objectives of the 2017 aquatic health assessments were to continue to measure the physical and chemical characteristics of the lake sediment, assess sediment toxicity, assess fish tissue mercury loading, and compare the results with appropriate environmental quality guidelines.

2.1 SAMPLING LOCATIONS

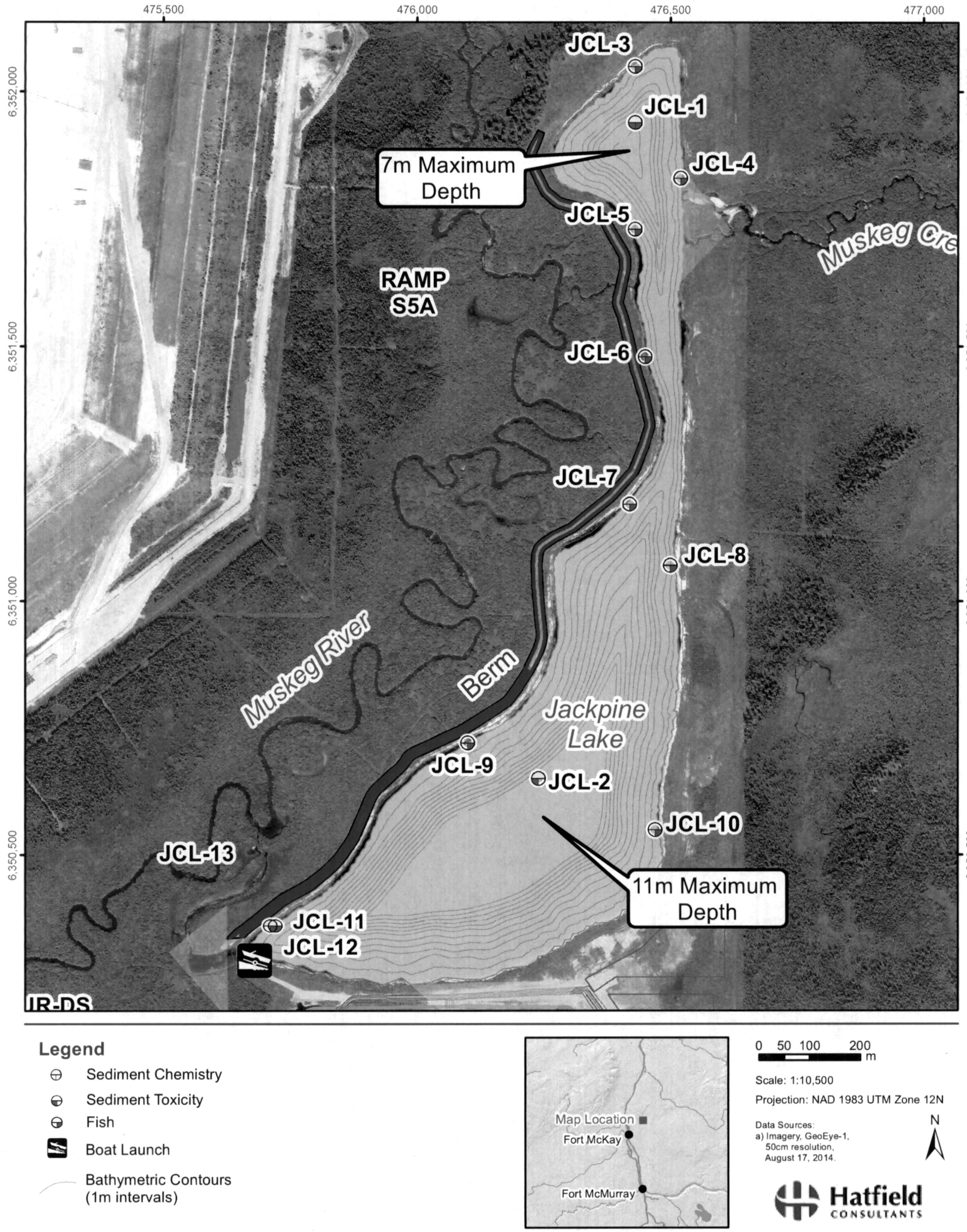
The 2017 Program collected samples from 12 sites located around the lake perimeter and body, which served as fishing and sediment sampling locations (Table 2.1). Two of the sites (JCL-1 and JCL-2) are deep sites with maximum depths of approximately 7 and 11 m, respectively. The other sites are positioned around the shoreline of the lake (Figure 2.1).

Table 2.1 Sampling coordinates and sampling techniques.

Station Type	Station Name	UTM Coordinates	Sampling Techniques
Deep-water	JCL-1	12U 476432 E 6351944 N	Sed Chem, Tox
	JCL-2	12U 476240 E 6350651 N	Sed Chem, Tox
Littoral	JCL-3	12U 476428 E 6352048 N	EF
	JCL-4	12U 476521 E 6351833 N	EF
	JCL-5	12U 476425 E 6351726 N	EF
	JCL-6	12U 476453 E 6351484 N	EF
	JCL-7	12U 476420 E 6351191 N	EF
	JCL-8	12U 476503 E 6351071 N	EF
	JCL-9	12U 476100 E 6350718 N	EF, AN
	JCL-10	12U 476469 E 6350548 N	EF, AN
	JCL-11	12U 475718 E 6350361 N	EF, AN
	JCL-12	12U 475713 E 6350362 N	Sed Chem, EF, AN

Note: EF = Electrofishing, AN = Angling, Sed Chem = Sediment Chemistry, TOX = Toxicity sampling

Figure 2.1 Sampling locations for the Jackpine Lake Monitoring Program.



K:\Data\Project\SHELL8642\A_MXD\SHELL8642_FieldSampling_20180329_v0_3_TD.mxd

2.2 FIELD SAMPLING PROGRAM

The aquatic health assessments of Jackpine Lake were carried out by S. McGrath and K. Roberts in 2017. Sampling activities are outlined in Table 2.2. The weather was a mix of rain and sun, and temperatures varied from 0 to 5°C.

Table 2.2 Field program activities completed in 2017.

Date	Activities
Oct 17	Travel to site, sediment sampling at JCL-1, JCL-2, and LIT-1
Oct 18	Electrofishing and fish processing
Oct 19	Angling, fish processing, and travel home

2.2.1 Record Keeping

A field notebook was kept for the duration of the field program to document weather, hourly activities, and any noteworthy wildlife sightings and/or relevant contact with site personnel. Field data sheets were filled out promptly and include fishing effort, fish data (length, weight, etc.), and supporting sediment and water quality observations. All relevant coordinates were recorded on data sheets and in field notebooks. Photos were taken of the site, of sediment sampling, and of select captured fish.

The appendices present a report on the QA/QC program (Appendix A1), summarized data records for sediment quality (Appendix A2), the analytical laboratory reports for sediment quality and toxicity (Appendices A2.1 and A2.2), the fish capture and processing records (Appendix A3), and the analytical laboratory reports for fish ageing and tissue analyses (Appendix A4).

2.2.2 Sediment

At each station, sediments were collected with a 15cm x 15cm Ekman grab (0.023 m^2 sampling area). To minimize potential for sample contamination at each station, pans, spoons, and the dredge were cleaned with a metals-free soap (i.e., Alconox), rinsed with hexane, rinsed with acetone, and triple-rinsed with ambient water prior to each sample collection. A grab sample was successful if the jaws closed completely and the sampler contained adequate sediment. Successful grabs were transferred to a stainless-steel pan until a sufficient volume had been collected for analysis. The number of grabs required to obtain sufficient volume was recorded. The sediments were then homogenized in the pan using a stainless-steel spoon and transferred into sterilized glass jars for chemical analyses and sealable plastic bags for the particle size and total organic carbon (TOC) analyses and sediment toxicity assays. Each container was labeled with the site name, collection date and time, and the analysis requested. All sediment samples were kept in coolers and maintained at approximately 4°C. Samples were packed with ice for shipment. All chemical and physical analyses were conducted by ALS (Edmonton, Alberta), except PAHs, which were analyzed by SGS-AXYS (Sidney, British Columbia). Sediment toxicity bioassays were completed by Maxxam Analytics (Burnaby, British Columbia).

2.2.3 Fish

The 2017 assessment targeted northern pike as the sentinel species for fish health and mercury accumulation. Fish were caught using angling and electrofishing methods to collect sufficient sample sizes while also minimizing capture stress and injury.

Boat electrofishing was conducted using a Smith-Root 2.5 GPP portable electrofisher with dual boom arrays and one dip-netter; sampling using 1 x 100 m transects parallel to shore was performed at all stations, beginning with the southern littoral area that was the most productive habitat in previous years. Mean electrofishing effort was 140 s in 2017. The start and end coordinates of each transect were recorded along with the fishing effort (Appendix A3). Electrofisher settings were consistent with previous Jackpine Lake fish capture programs: 60hz, 60dc, and Low power.

Angling consisted of 15 minutes of spin-casting from near-shore stations using an assortment of fishing tackle. UTM coordinates of each angling location and the length of time spent fishing are documented in Appendix A3.

All captured large-bodied fish were identified to species, weighed with a digital hanging (50 kg ± 20 g) or tabletop scale (400 g ± 0.01 g), measured (± 1 mm fork length), and examined for passive integrated transponder (PIT) tags. All fish greater than 150 mm in length received PIT tags, to allow recapture data to be generated during future sampling events. PIT tags were inserted into the ventral area of the abdominal cavity midway between the pectoral and pelvic fins using an MK10 syringe-style implanter. A Biomark 601 handheld reader was used to scan captured large-bodied fish for the presence of previously deployed PIT tags. Anal fin rays were collected from each northern pike for ageing analysis, using protocols described in MacKay et al. (1990); the minimum size for non-lethal ageing structure collection was 150 mm. The fin rays were placed in scale envelopes to dry, and shipped to North/South Consultants (Winnipeg, MB) for age determination.

A 4-mm dermal punch was used to collect non-lethal tissue samples from each northern pike that measured >150 mm. Samples were placed in sterile 2 g cryovials and were immediately flash frozen on dry ice to prevent moisture loss due to evaporation. Samples were shipped on dry ice to Flett Research (Winnipeg, MB) for mercury analysis.

2.3 SAMPLE ANALYSIS

2.3.1 Sediment Quality

Lake sediments were analyzed by accredited laboratories (ALS Environmental, Edmonton, AB; SGS AXYS, Sydney, BC) for the Joint Oil Sands Monitoring Plan (JOSMP) standard suite of variables (Table 2.3). Sample results were compared against CCME interim sediment quality guidelines (ISQG), which represent the concentration below which adverse biological effects to aquatic biota rarely occur, and probable effects levels (PEL), which represent the concentration that is expected to cause adverse effects to aquatic biota (AESRD 2014; CCME 2011). The compiled 2017 sediment quality data are presented in Appendix A2, and the reports from the analytical laboratories are provided in Appendix A2.1.

2.3.1.1 PAH

Estimation of PAH toxicity in Jackpine Lake sediments was conducted using the Neff et al method (2004), which incorporates 41 individual PAH compounds into the calculation. Sediments comprised of petrogenic PAH sources such as those found in the Athabasca oil sands region (i.e., PAHs dominated by alkylated PAHs relative to parent PAHs; Table 2.3) have a higher affinity to non-aqueous phase liquids (NAPL) than to sediment organic matter, and this affinity drives the partitioning between the three sediment phases of porewater, sediment organic material, and NAPL. This affinity for NAPL is important as other methods, such as those described by the US Environmental Protection Agency (USEPA 2004), rely on concentrations of total organic carbon to normalize PAH concentrations in the hazard index calculation. The Neff method is also preferable because it incorporates more individual PAH compounds into the PAH toxicity calculation (41 individual compounds) than the USEPA method (13, 23, or 34 depending on variation), thereby providing a more accurate representation of potential PAH toxicity.

The Neff method (described below) requires that each individual PAH measurement first be normalized to a measure of total recoverable hydrocarbons, to produce an estimate of the combined PAH concentration that is available in porewater and the organic sediment fraction. Values for PAH concentrations and total CCME hydrocarbons (used to estimate total recoverable hydrocarbons) were obtained through laboratory analysis.

$$PAH_{(normalized)} = \frac{PAH\ concentration}{total\ recoverable\ hydrocarbons}$$

Where:

- $PAH_{(normalized)}$ refers to the estimate of PAHs available in porewater and complexed to the organic fraction of sediment particles; and
- Total recoverable hydrocarbons are estimated by the equation:

$$Total\ recoverable\ hydrocarbons = total\ CCME\ hydrocarbons * 2.183$$

Normalized PAH concentrations are divided by a K_{ow} partition coefficient, thereby removing the portion of PAHs complexed to sediments and estimating the concentration available in porewater alone; this provides the bioavailable amount of each PAH. The porewater estimate is further divided by a chronic toxicity value for water (Mackay et al 1992, Neff and Burns 1996, and Ran et al 2002, as cited in Neff et al 2004) to produce a hazard quotient (HQ) for each PAH measured in the sediment sample:

$$HQ = \left(\frac{PAH_{(normalized)}}{K_{ow}}\right) \div Chronic\ Toxicity\ value$$

The hazard quotients are then summed to produce a hazard index (HI) for total PAHs in sediment porewater.

2.3.2 Sediment Toxicity

Sublethal (chronic) toxicity testing provides an effects-based assessment of sediment quality by comparing the survival and growth of amphipods *(Hyalella azteca)* and chironomids *(Chironomus dilutus)* exposed to lake sediments against the responses of test organisms exposed to laboratory-supplied control sediments (Environment Canada 2010). A magnitude difference of >20% between any test and control group endpoint was considered ecologically significant (CCME 1995).

Table 2.3 Physical, chemical, and biological variables measured in sediments collected from Jackpine Lake, 2017.

Group	Sediment Quality Variable		
Physical variables	Percent sand	Texture	Moisture content
	Percent silt	Percent clay	Total carbon by combustion
Carbon content	Total inorganic carbon	Total organic carbon	
Total metals	Aluminum	Copper	Selenium
	Antimony	Iron	Silver
	Arsenic	Lead	Sodium
	Barium	Lithium	Strontium
	Beryllium	Magnesium	Thallium
	Bismuth	Manganese	Tin
	Boron	Mercury	Titanium
	Cadmium	Molybdenum	Uranium
	Calcium	Nickel	Vanadium
	Chromium	Phosphorus	Zinc
	Cobalt	Potassium	Zirconium
Organics	CCME 4-fraction total hydrocarbons:	- F3 (C16-C34)	BTEX (Benzene, Toluene, Ethylene, Xylene)
	- F1 (C6-C10)	- F4 (C34-C50)	
	- F2 (C10-C16)	Total hydrocarbons (C6-C50)	
Parent PAHs	Acenaphthene	Benzo(g,h,i)perylene	
	Acenaphthylene	Biphenyl	Indeno(c,d-123)pyrene
	Anthracene	Dibenzo(a,h)anthracene	Naphthalene
	Benzo(a)anthracene	Dibenzothiophene	Phenanthrene
	Benzo(a)pyrene	Fluoranthene	Pyrene
	Benzo (b,j,k) fluoranthene	Fluorene	

Table 2.3 (Cont'd.)

Group	Sediment Quality Variable	
Alkylated PAHs	C1-substituted acenaphthene	C3-substituted fluoranthene/pyrene
	C1-substituted benzo(a)anthracene/chrysene	C1-substituted fluorene
	C2-substituted benzo(a)anthracene/chrysene	C2-substituted fluorene
	C1-substituted biphenyl	C3-substituted fluorene
	C2-substituted biphenyl	C1-substituted naphthalenes
	C1-substituted benzofluoranthene/ benzo(a)pyrene[1]	C2-substituted naphthalenes
	C2-substituted benzofluoranthene/benzo(a)pyrene[1]	C3-substituted naphthalenes
	C1-substituted dibenzothiophene	C4-substituted naphthalenes
	C2-substituted dibenzothiophene	C1-substituted phenanthrene/anthracene
	C3-substituted dibenzothiophene	C2-substituted phenanthrene/anthracene
	C4-substituted dibenzothiophene	C3-substituted phenanthrene/anthracene
	C1-substituted fluoranthene/pyrene	C4-substituted phenanthrene/anthracene
	C2-substituted fluoranthene/pyrene	1-methyl-7-isopropyl-phenanthrene (retene)[2]
Sublethal toxicity testing	Survival and growth of the amphipod *Hyalella azteca*	
	Survival and growth of *Chironomus dilutus* midge larvae	

[1] Concentration not included in PAH toxicity calculation for sediments (Neff et al 2004).

[2] The calculation total PAHs does not include retene because it is included in the measurement of C4-substituted phenanthrene/anthracene.

2.3.3 Fish

Morphology measurements (i.e., length and weight) were collected from all captured fish (Section 2.2.3). Aging structures (anal fin rays) were collected and analyzed by North/South Consultants using standard enumeration of annuli (Appendix A4). Fish condition was assessed using Fulton's condition factor and relative weights (Blackwell et al. 2000). Fluctuations in fish condition over time may indicate changes in the availability of food or environmental quality. Fulton's conditions factor is based on an isometric relationship between length and weight. Heavier fish for a given length have a higher condition factor, which may be associated with higher food quality and environmental conditions. The relative weight condition factor is determined as the ratio between the observed weight and the standard weight derived for that species. Standard weights are determined empirically from studies on the distribution of lengths and weights in unimpacted natural populations (Willis 1989). Captured individuals with observed weights greater than the standard weight are heavier than would be predicted by length, and may represent fish from higher quality environments.

Fish tissue mercury concentrations were measured by Flett Research Ltd. (Winnipeg, MB) by digestion, ethylation, and cold-vapour atomic fluorescence spectroscopy (Appendix A4). Total mercury was measured in tissue samples from 2012 to 2016. However, in 2017, the tissue samples were erroneously analyzed for total methyl-mercury only. Organisms actively excrete elemental mercury and mercury ions (e.g., Hg^{1+} or Hg^{2+}), whereas the methyl-mercury accumulates in tissues. Previous studies have shown approximately 100% of the mercury in pike and other piscovorous fish is in the form of methyl-mercury (Bloom 1992, Duffy et al 1999, Jackson 1990, Jewett et al 2003, Lasorsa and Allen-Gill 1995). The high correspondence between tissue total mercury and total methyl-mercury concentrations in other studies support the direct comparison of the 2017 tissue mercury data to the earlier results in the Program. However, some uncertainty remains because of the potential underestimation of tissue total mercury concentrations.

3.0 RESULTS AND DISCUSSION

3.1 SEDIMENTS

The sediment monitoring component assesses two indicators of environmental quality: the physico-chemical characteristics of the sediments, and the potential for the sediments to cause mortality or inhibit growth in controlled laboratory assays using cultured organisms. These two indicators are discussed separately in the following sections.

3.1.1 Physio-Chemical Characteristics

Sediment quality in Jackpine Lake continues to develop since the commissioning of the lake. The relative proportions of finer silts and clays are increasing, along with the concentration of organic matter (Table 3.1). Proportions of finer particles and organic matter were near or greater than observations from previous years. Similarly, the concentrations of many metals were near or greater to the range of previous observations. Metals readily adsorb to organic matter and clays, so the observed increase in sediment metal concentrations may be a consequence of the decrease in the relative proportion of sand-sized particles and the corresponding increase of fine clay-sized particles and organic matter. All metal

concentrations have remained below applicable environmental quality guidelines for the protection of aquatic life since the start of the Program in 2010.

The concentrations of most PAH and petroleum hydrocarbons in 2017 were within the range of observations from the early phase of the lake. Some hydrocarbons (i.e., benzene, ethylbenzene, and CCME Fraction 1 hydrocarbons) were detectable at the northern sampling site (JCL-1). The largest observed changes were decreases in the concentrations of petroleum hydrocarbons at the southern site (JCL-2) in 2017. A number of petroleum hydrocarbon analytes had concentrations greater than their environmental quality guidelines at the deep-water monitoring locations, which was generally consistent with observations of higher concentrations from 2016 and earlier. Analytes with concentrations higher than guidelines included:

- F3 petroleum hydrocarbons (C16 to C34);
- acenaphthene;
- chrysene; and
- phenanthrene.

3.1.1.1 PAH Toxicity

The toxicity of PAH in the Jackpine Lake sediments was inferred from hazard quotients described in Section 2.3.1.1. The predicted PAH toxicity in 2017 was lower than the average predicted toxicity during the early phase of the lake for both the northern mid-lake and the littoral sampling stations. In general, the predicted toxicity at both stations was substantially lower than the early phase of the lake, which may represent a general decrease in the overall concentration of potentially toxic PAH compounds in the sediments.

In contrast, the predicted PAH toxicity at the south mid-lake station was substantially higher in 2017, relative to all previous years of sampling. This increase was the result of a substantial decrease in the estimate of the concentration of petroleum hydrocarbons, and not the result of an increase in the concentrations of PAH. The method for calculating PAH toxicity includes a standardization of PAH concentrations to overall hydrocarbon concentration. In the case of the 2017 PAH toxicity prediction, the substantially lower petroleum hydrocarbon concentrations inflated the standardized concentrations of PAH, which in turn increased the predicted PAH toxicity. The overall trend in predicted PAH toxicity was therefore generally decreasing throughout Jackpine Lake, but the 2017 result from the southern mid-lake site did demonstrate some uncertainty stemming from the assessment approach.

This page intentionally left blank for printing purposes.

Table 3.1 Summary of physio-chemical characteristics of sediment in Jackpine Lake, 2010 to 2017.

Measurement Variable	Units	Guideline		North Basin (JCL-1)				South Basin (JCL-2)				Littoral Zone (JCL-12)			
		ISQG	PEL	2017	2010 to 2016			2017	2010 to 2016			2017	2010 to 2016		
					Min	Average	Max		Min	Average	Max		Min	Average	Max
Physical Variables															
Moisture	%	-	-	65	0.18	32	71	41	0.2	32	67	51	0.1	43	73
Total Organic Carbon	%	-	-	11	0.62	4.7	12	3	1	2	3.7	4	0.76	4.9	10
Sand	%	-	-	17	28	68	93	59	32	69	83	70	60	77	94
Silt	%	-	-	70	4.8	22	51	17	8	17	49	23	4.8	14	24
Clay	%	-	-	13	2.5	9.5	27	24	7.9	15	20	7	1.2	8.5	16
Texture	-	-	-	Silt loam	Sand	Sandy loam	Loam/Clay loam	Sandy clay loam	Sandy loam	Loamy sand	Loamy sand	Sandy loam	Sand	Sandy loam	Sandy loam
Total Petroleum Hydrocarbons															
Benzene	mg/kg	-	-	0.013	<0.0050	n/a	<0.010	<0.0050	<0.005	n/a	<0.015	<0.0050	<0.0050	n/a	<0.010
Ethylbenzene	mg/kg	-	-	0.015	<0.015	n/a	<0.06	<0.010	<0.012	n/a	<0.045	<0.010	<0.015	n/a	<0.06
Toluene	mg/kg	-	-	<0.050	0.038	0.11	0.26	<0.050	<0.019	n/a	<0.15	<0.050	<0.05	n/a	<0.2
Xylenes	mg/kg	-	-	<0.10	<0.10	n/a	<0.4	<0.10	<0.1	n/a	<0.3	<0.10	<0.10	n/a	<0.4
Fraction 1 (C6-C10)	mg/kg	30	-	11	<10	n/a	<40	12	<10	n/a	<30	10	<30	n/a	<20
Fraction 2 (C10-C16)	mg/kg	150	-	110	<20	83	***185***	36	65	***168***	***479***	20	<20	74	145
Fraction 3 (C16-C34)	mg/kg	300	-	***1500***	51	***824***	***2080***	290	***653***	***1476***	***3600***	***580***	***304***	***794***	***1280***
Fraction 4 (C34-C50)	mg/kg	2800	-	1160	27	580	1390	200	401	901	2000	480	116	467	832
Select Polycyclic Aromatic Hydrocarbons															
Total PAHs	mg/kg	-	-	14	4.6	13	28	21	6.8	18	28	2.7	1.3	6.3	16
Total Parent PAHs	mg/kg	-	-	0.3	0.13	0.3	0.71	0.36	0.2	0.41	0.68	0.094	0.039	0.17	0.36
Total Alkylated PAHs	mg/kg	-	-	14	4.5	13	28	20	6.7	17	28	2.6	1.3	6.1	15
Predicted PAH toxicity	HI	-	-	**1.5**	0.82	**9.5**	**43**	**11**	**1.3**	**2.3**	**3.4**	0.70	0.59	**1.3**	**2.3**
Acenaphthene	mg/kg	0.00671	0.0889	0.0063	0.0013	***0.012***	***0.034***	***0.016***	0.003	***0.02***	***0.038***	0.00076	0.00076	0.0056	***0.013***
Acenaphthylene	mg/kg	0.00587	0.128	0.00027	<0.000051	0.00044	0.00072	0.00039	0.00024	n/a	<0.0028	0.00018	<0.000059	n/a	<0.0031
Anthracene	mg/kg	0.0469	0.245	<0.0012	<0.00045	n/a	<0.0053	<0.0029	<0.00085	n/a	<0.014	0.00054	<0.00027	n/a	<0.012
Benzo[a]anthracene	mg/kg	0.0317	0.385	0.012	0.0011	0.013	0.030	0.017	<0.0064	0.018	***0.034***	0.0021	0.00075	0.0075	0.02
Benzo[a]pyrene	mg/kg	0.0319	0.782	0.010	0.0012	0.0090	0.019	0.014	0.0055	0.011	0.021	0.0035	0.00088	n/a	<0.014
Chrysene	mg/kg	0.0571	0.862	***0.11***	0.012	***0.09***	***0.18***	***0.12***	0.045	***0.11***	***0.17***	0.029	0.0086	***0.06***	***0.14***
Dibenz[a,h]anthracene	mg/kg	0.00622	0.135	0.0062	0.00063	0.0042	***0.0065***	0.005	0.0024	0.0046	0.0062	0.0037	0.00041	n/a	<0.011
Fluoranthene	mg/kg	0.111	2.355	0.0068	0.00099	0.0062	0.015	0.011	<0.0028	0.01	0.015	0.0016	0.0017	n/a	<0.012
Fluorene	mg/kg	0.0212	0.144	0.0039	0.00039	0.0027	0.0053	0.0030	0.0017	0.0042	0.0093	0.00063	0.00023	0.0021	0.0067
Naphthalene	mg/kg	0.0346	0.391	0.0018	0.00092	0.0018	0.0027	0.0012	0.0014	0.0019	0.0032	0.0012	0.00073	0.0022	0.0033
Phenanthrene	mg/kg	0.0419	0.515	***0.052***	0.0083	***0.069***	***0.24***	***0.096***	0.021	***0.13***	***0.25***	0.0077	0.0061	0.031	***0.095***
Pyrene	mg/kg	0.053	0.875	0.033	0.0048	0.03	***0.057***	0.036	0.020	0.033	0.045	0.0092	0.008	0.022	0.044

Table 3.1 (Cont'd.)

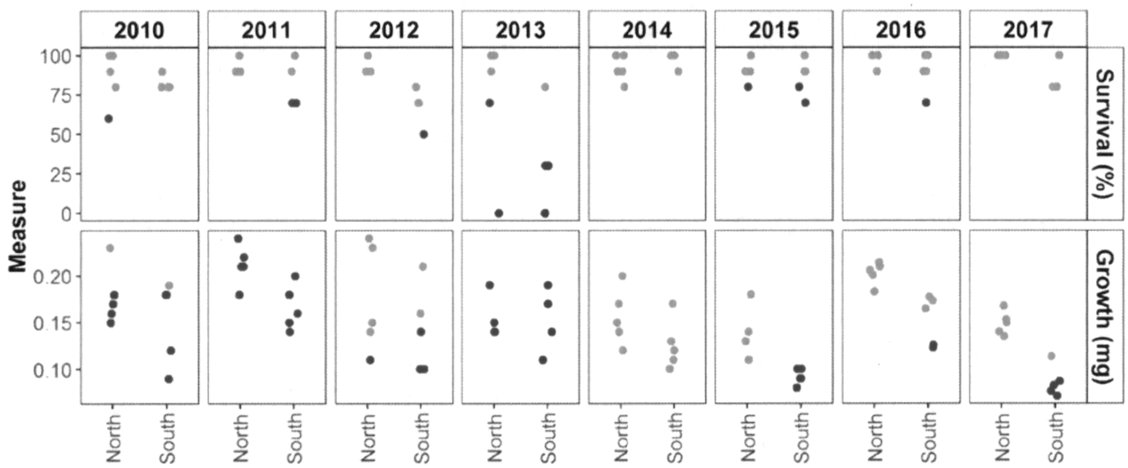
Measurement Variable	Units	Guideline		North Basin (JCL-1)				South Basin (JCL-2)				Littoral Zone (JCL-12)			
		ISQG	PEL	2017	2010 to 2016			2017	2010 to 2016			2017	2010 to 2016		
					Min	Average	Max		Min	Average	Max		Min	Average	Max
Metals															
Aluminum	mg/kg	-	-	5860	<0.2	2375	7500	5300	0.24	3493	6200	2210	<0.2	1915	3740
Antimony	mg/kg	-	-	<0.1	0.087	0.1	0.12	0.12	<0.05	n/a	<0.1	<0.1	<0.05	0.15	0.52
Arsenic	mg/kg	5.9	17	3.1	0.41	1.4	3.2	2.0	1.2	2	2.9	1.3	0.51	1.4	2.9
Barium	mg/kg	-	-	83	9.2	43	107	50	26	42	67	36	11	33	60
Beryllium	mg/kg	-	-	0.39	0.17	0.27	0.45	0.34	0.18	0.27	0.47	0.15	<0.1	0.18	0.23
Bismuth	mg/kg	-	-	<0.2	<0.1	n/a	<0.2	<0.2	<0.1	n/a	<0.2	<0.2	<0.1	0.2	0.43
Cadmium	mg/kg	0.6	3.5	0.16	0.04	0.11	0.18	0.063	0.036	n/a	<0.1	0.063	0.03	0.085	0.11
Calcium	mg/kg	-	-	12900	3240	7662	16900	4390	3750	6084	9190	4310	2740	6108	9030
Chromium	mg/kg	37.3	90	11	1.6	6.1	14	9.6	6.7	8.6	13	4.6	2.6	4.8	9.1
Cobalt	mg/kg	-	-	6.2	0.65	2.8	6.2	3.8	2.3	3.4	5	2.1	0.81	1.8	3.1
Copper	mg/kg	35.7	197	8.7	1.5	4.4	9.6	6.1	4.3	5.2	7.6	3	1.6	3.3	5.3
Iron	mg/kg	-	-	15600	1740	7061	16800	10500	6500	10336	17200	6500	1960	4983	8630
Lead	mg/kg	35	91.3	5.9	0.97	3	6.3	4.3	2.5	3.8	5.5	2.1	1.1	2	3.2
Lithium	mg/kg	-	-	6.8	0.88	4.8	12	5.3	4.4	6.2	9.3	<2	1.1	3.1	5.4
Magnesium	mg/kg	-	-	3570	789	1756	3540	2240	1260	2063	3020	1150	726	1249	1640
Manganese	mg/kg	-	-	489	30	173	451	196	129	204	343	335	29	134	319
Mercury	mg/kg	0.17	0.486	0.036	0.029	n/a	<0.05	0.018	0.013	n/a	<0.05	0.013	0.013	n/a	<0.05
Molybdenum	mg/kg	-	-	0.5	<0.1	0.3	0.64	0.35	0.22	0.37	0.52	0.26	0.13	0.3	0.48
Nickel	mg/kg	-	-	12	1.5	6.3	14	8.8	5.3	8	12	5	2.1	4.9	8.6
Phosphorus	mg/kg	-	-	517	<100	207	492	261	114	189	312	215	<100	177	327
Potassium	mg/kg	-	-	830	<100	414	1080	780	428	616	890	380	140	334	580
Selenium	mg/kg	-	-	0.25	<0.1	0.22	0.33	<0.2	<0.1	0.19	0.24	<0.2	<0.1	0.19	0.25
Silver	mg/kg	-	-	<0.1	<0.05	n/a	<0.2	<0.1	<0.05	n/a	<0.2	<0.1	<0.05	n/a	<0.2
Sodium	mg/kg	-	-	170	49	101	141	90	50	n/a	<100	72	36	n/a	<100
Strontium	mg/kg	-	-	42	6.7	24	54	21	16	23	35	20	8.6	22	34
Thallium	mg/kg	-	-	0.088	<0.05	n/a	<0.2	0.072	<0.05	n/a	<0.2	<0.05	<0.05	n/a	<0.2
Tin	mg/kg	-	-	<2	0.15	n/a	<2	<2	0.17	n/a	<2	<2	0.11	n/a	<2
Titanium	mg/kg	-	-	34	22	40	68	51	50	64	77	32	30	44	65
Uranium	mg/kg	-	-	0.85	0.14	0.41	0.95	0.41	0.24	0.52	1.3	0.31	0.17	0.35	0.63
Vanadium	mg/kg	-	-	20	2.6	9.9	23	17	8.8	14	20	8	3.6	7.3	12
Zinc	mg/kg	123	315	40	<5	19	46	20	11	18	26	13	<5	13	22

Notes:
Value greater than the range of 2010 to 2016 observations at that sampling location.
Value less than the range of 2010 to 2016 observations at that sampling location.
Observations less than or equal to analytical detection limits.
Bold-italic values are greater than interim sediment quality guidelines (ISQG) for the protection of aquatic life.
<u>***Underlined bold-italic***</u> values are greater than probable effects level threshold for the protection of aquatic life.
Predicted PAH toxicity does not have guidelines for the protection of aquatic life. Values greater than 1 are highlighted in **bold.**

3.1.2 Sediment Toxicity

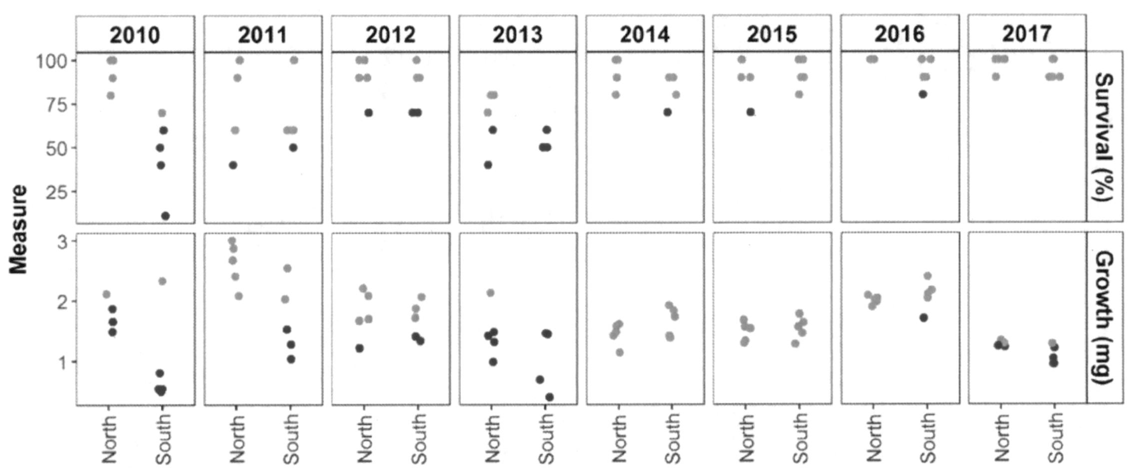
Jackpine Lake sediments collected in 2017 did not affect the survival of invertebrates (Figure 3.1 and Figure 3.2). Larger effects on the growth of invertebrates were observed in samples from the southern mid-lake station in 2017; four out of the five 2017 replicates from the southern mid-lake station had reduced growth in *Chironomus* and *Hyallela* relative to the growth in the controls.

Figure 3.1 Toxicity assay results for *Hyalella azteca* during static exposures to Jackpine Lake sediments, 2010 to 2017.



Shown are the results of sediment toxicity assays using the amphipod Hyalella from 2010 to 2017. Toxicity endpoints (i.e., survival and growth) more than 20% different from the mean of parallel control assays are labelled with green symbols.

Figure 3.2 Toxicity assay results for *Chironomus dilutus* during static exposures to Jackpine Lake sediments, 2010 to 2017.



Shown are the results of sediment toxicity assays using the dipteran Chironomus from 2010 to 2017. Toxicity endpoints (i.e., survival and growth) more than 20% different from the mean of parallel control assays are labelled with green symbols.

Over the longer term, sediment toxicity appears to be decreasing. Since commissioning of the lake, the proportion of assays with significant reductions in survival or growth (i.e., the green symbols on Figure 3.1 and Figure 3.2), have decreased at both sediment sampling stations.

3.1.3 Sediment Quality Assurance and Quality Control Results

The sediment quality samples were collected in adherence to the SOP and FWI, and were analyzed by accredited analytical laboratories. No data quality flags were identified in the analytical reports, with the exception of measurements less than analytical detection limits and measurements less than the analytical quantification limits. As a result of adherence to the SOP and the laboratory QA/QC results, the sediment quality data were concluded to meet the data quality objectives for the program.

3.2 FISH

3.2.1 Fish Capture Locations and Rates

The minimum criteria set out for a fishing method to be acceptably productive in this study was a minimum of 3 fish per hour; if this minimum was not met, another method was employed. While catch rates varied from site to site, fishing rates in 2017 were high for both electrofishing and angling, with average captures of 0.5 fish per 100 s and 8 fish per hour, respectively (Table 3.2).

33 northern pike were captured in 2017. Fish over 150 mm were the focus of this study, to allow aging structures and tissue plugs to be collected without causing undue harm to the fish. Three of the 2017 pike were recaptures, including one with a Floy tag from an unknown project that would have occurred outside of Jackpine Lake. The other two tags were deployed during the 2012 Jackpine Lake Monitoring Program (Table 3.3) No tissue mercury measurements were made on the recaptured fish in 2012, while the two individuals differed substantially in growth between 2012 and 2017; one recaptured fish increased nearly six-fold in weight while the other increased by less than three-fold. Interestingly, both of the fish tagged by the Program were recaptured at the same locations in the Lake. No other fish species were seen or captured in 2017.

Table 3.2 Angling and electrofishing effort and rates, October 2017.

Type	Pass/Set number	Effort		Number fish captured	CPUE	
		(sec)	(hour)		(fish/hr)	(fish/100 sec)
EF	JCL-12	111	-	0	-	0
EF	JCL-11	103	-	2	-	1.9
EF	JCL-9 (1)	110	-	0	-	0
EF	JCL-9 (2)	147	-	3	-	2.0
EF	JCL-7	141	-	1	-	0.7
EF	JCL-6	207	-	0	-	0
EF	JCL-5	123	-	0	-	0
EF	JCL-3	124	-	1	-	0.8
EF	JCL-4	143	-	0	-	0
EF	JCL-8	158	-	1	-	0.6
EF	JCL-10	157	-	0	-	0
EF	P1	2067	-	13	-	0.6

Table 3.2 (Cont'd.)

Type	Pass/Set number	Effort		Number fish captured	CPUE	
		(sec)	(hour)		(fish/hr)	(fish/100 sec)
AN	AN1 (JCL-3)	-	0.25	0	0	-
AN	AN2 (JCL-10)	-	0.25	0	0	-
AN	AN3 (JCL-11)	-	0.25	2	8	-
AN	AN4 (JCL-12)	-	0.25	2	8	-
AN	AN5 (JCL-11)	-	0.25	2	8	-
AN	AN6 (JCL-12)	-	0.37	6	16.4	-

Note: The closest sampling location (within ~50 m) for each angling event noted next to the event number.

Table 3.3 Northern pike recaptured during the 2017 fishing sampling program.

Fish ID	Capture Site		Length (mm)		Weight (g)		Estimated Age (years)		Tag number
	2012	2017	2012	2017	2012	2017	2012	2017	
13	JCL-8	JCL-8	410	740	540	3,210	2	7	AC957A3 / 982000180967331
23	JCL-5	JCL-5	408	547	500	1,480	4	9	AC95848 / 982000180967496
31	-	AN6 (JCL-12)	-	491	-	1140	-	n/a	SUSFE 0896 (unknown program)

3.2.2 Fish Biology

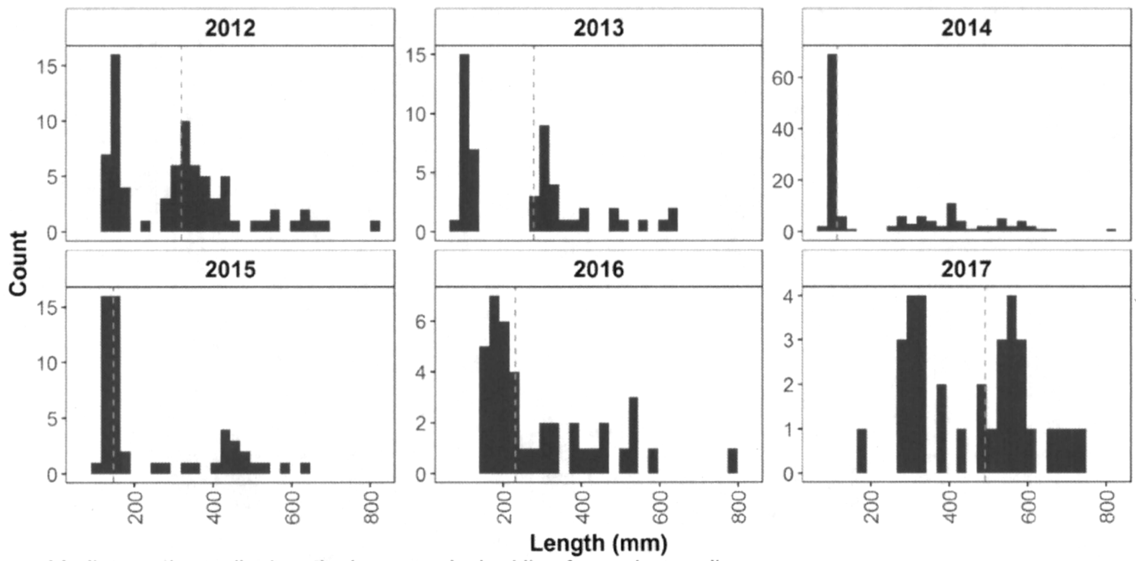
The overall distribution of northern pike lengths, weights, and ages has varied over time in Jackpine Lake (Figure 3.3, Figure 3.4, and Figure 3.5). Much of this variation was likely due to changes in fishing methods, which transitioned from gill nets, hoop nets, and seine nets in early study years to the targeted capture of larger northern pike in 2016 and 2017. A bimodal distribution in northern pike length and weight was observed in 2017, which had a larger proportion of larger fish than sampling in previous years (Figure 3.3 and Figure 3.4). The sampling program in 2017 captured the widest range of fish ages (Figure 3.5); this distribution of ages indicates Jackpine Lake provides habitat to a range of northern pike life stages, from juvenile fish through adults.

Both fish condition factors (i.e., Fulton's K and relative weight) indicated that the overall condition of northern pike in Jackpine Lake has been stable since 2012 (Figure 3.6 and Figure 3.7). Consistent condition factors would be expected for a relatively stable ecosystem, because the fish would grow at broadly similar rates if conditions and the supply of food do not vary. Although the consistent fish condition results indicate a relatively stable environment, additional studies would be required to confirm that gear bias is not selecting against heavier fish (if fish condition is increasing) or selecting against lighter fish (if fish condition is decreasing).

The length-age relationships of northern pike have varied over time (Figure 3.8). The length-at-age distributions in 2017 were similar to those observed in 2016, with similar median lengths-at-age and overlapping distributions. These similar length-at-age distributions indicate little change in the growth rate of fish between these two comparable sampling events. More variation was observed between the 2014

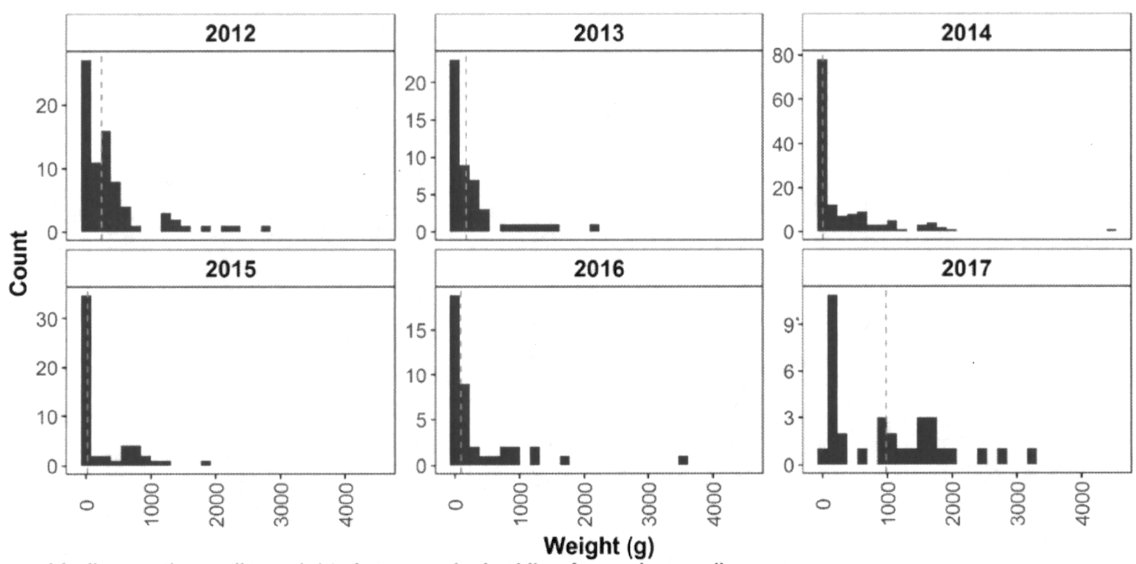
results and all other length-age observations (i.e., 2012, 2013, 2015, 2016, and 2017). It is not clear if there was increased growth in 2014, or the difference was the result of sampling bias or precision issues with the age estimates. Aging by fin clips for younger northern pike (i.e., less than 10 years) has a measurement uncertainty of ±1 year for average quality samples.

Figure 3.3 Lengths of northern pike captured from Jackpine Lake, 2012 to 2017.



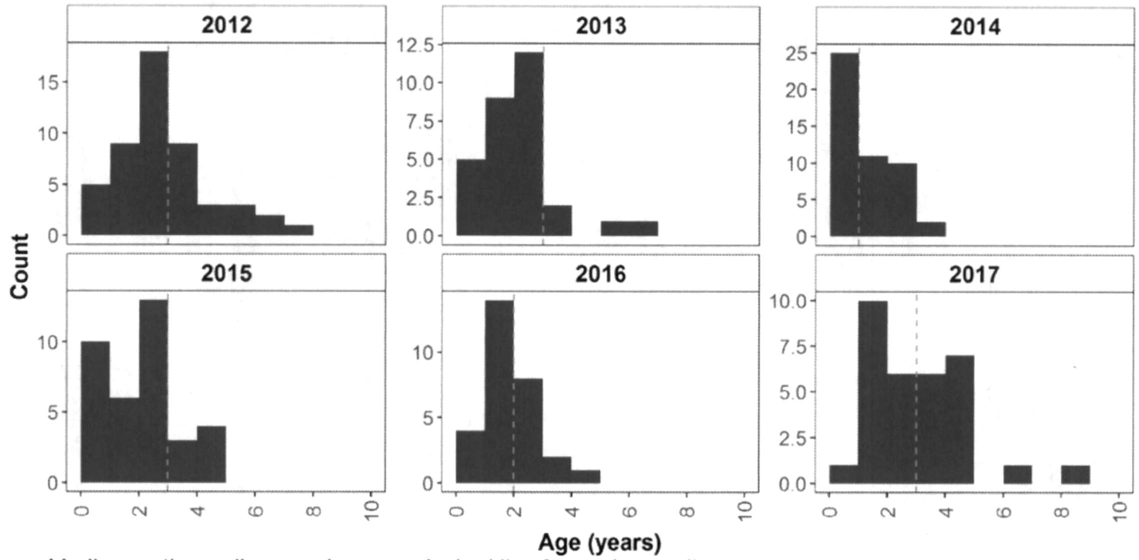
Median northern pike length shown as dashed line for each sampling year.

Figure 3.4 Weights of northern pike captured from Jackpine Lake, 2012 to 2017.



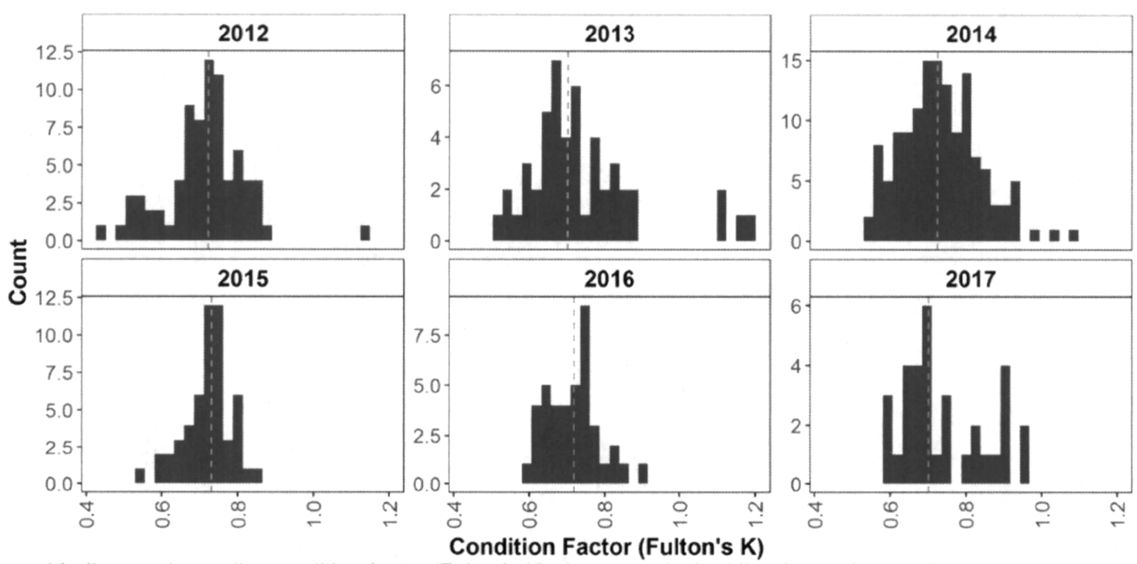
Median northern pike weight shown as dashed line for each sampling year.

Figure 3.5 Ages of northern pike captured from Jackpine Lake, 2012 to 2017.



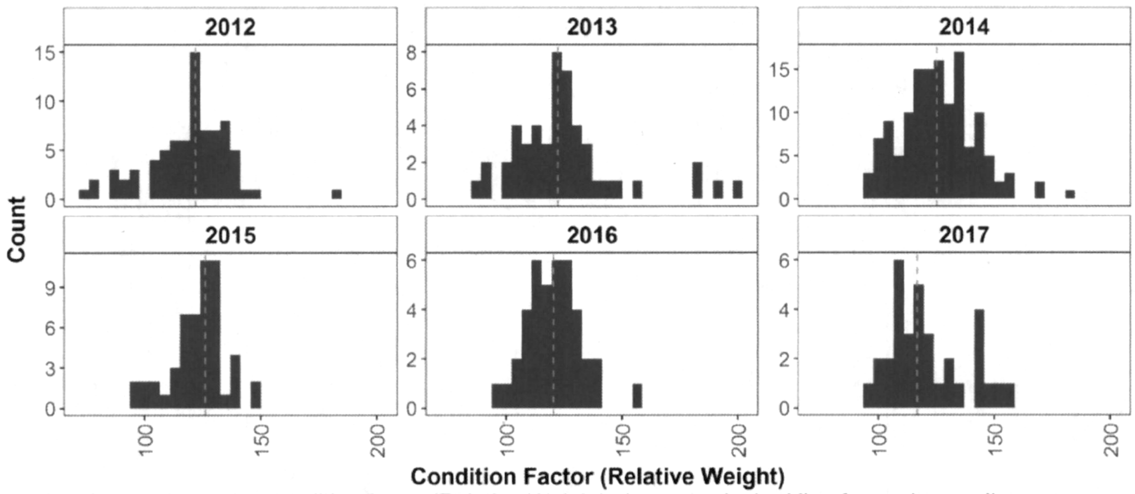
Median northern pike age shown as dashed line for each sampling year.

Figure 3.6 Condition factors (Fulton's K) of northern pike captured from Jackpine Lake, 2012 to 2017.



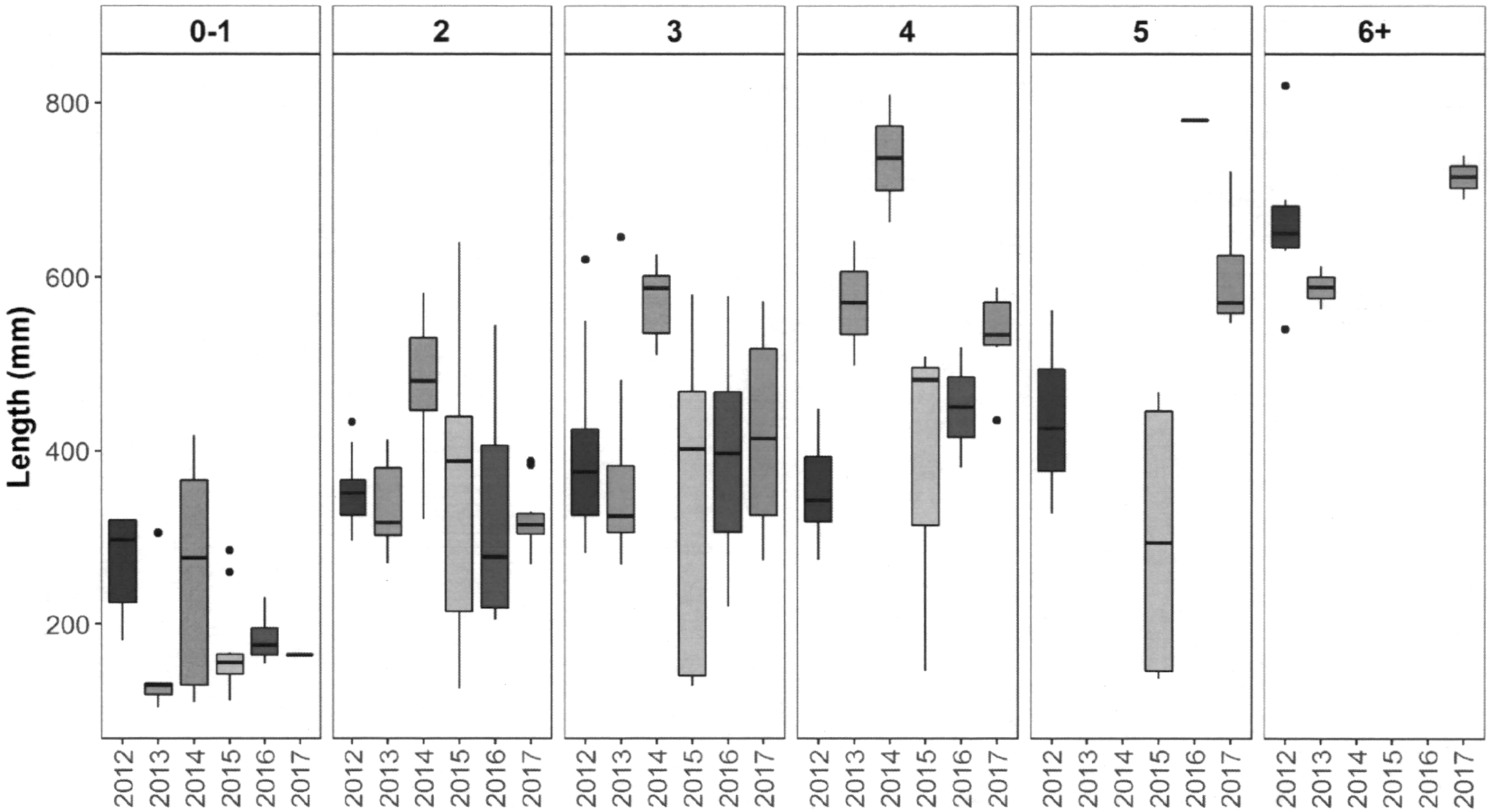
Median northern pike condition factor (Fulton's K) shown as dashed line for each sampling year.

Figure 3.7 Relative weights (Wr) for northern pike captured from Jackpine Lake, 2012 to 2017.



Median northern pike condition factor (Relative Weight) shown as dashed line for each sampling year. Relative weight is defined as the ratio between the observed weight and the standard weight developed by the equation for northern pike.

Figure 3.8 Length-age relationships for northern pike from Jackpine Lake, 2012 to 2017.



Boxplots show the median as the thick horizontal line, upper and lower quartiles as the bounds of the boxes, and whiskers show 1.5 times the IQR.

3.2.3 Mercury Concentrations in Fish Tissue

Median mercury concentrations of Jackpine Lake pike, across all ages of fish, were higher in 2017 compared to 2016, but remained lower than median concentrations observed in 2014 and 2015 (Table 3.4). The increase in median mercury concentrations may be the result of the capture of older fish in the 2017 program. The majority of fish captured in 2017 had tissue concentrations less than the Health Canada guideline for subsistence fishers (0.2 µg/g), and no fish captured in 2017 had tissue mercury concentrations greater than the Health Canada guideline for general consumers (Table 3.4 and Figure 3.9).

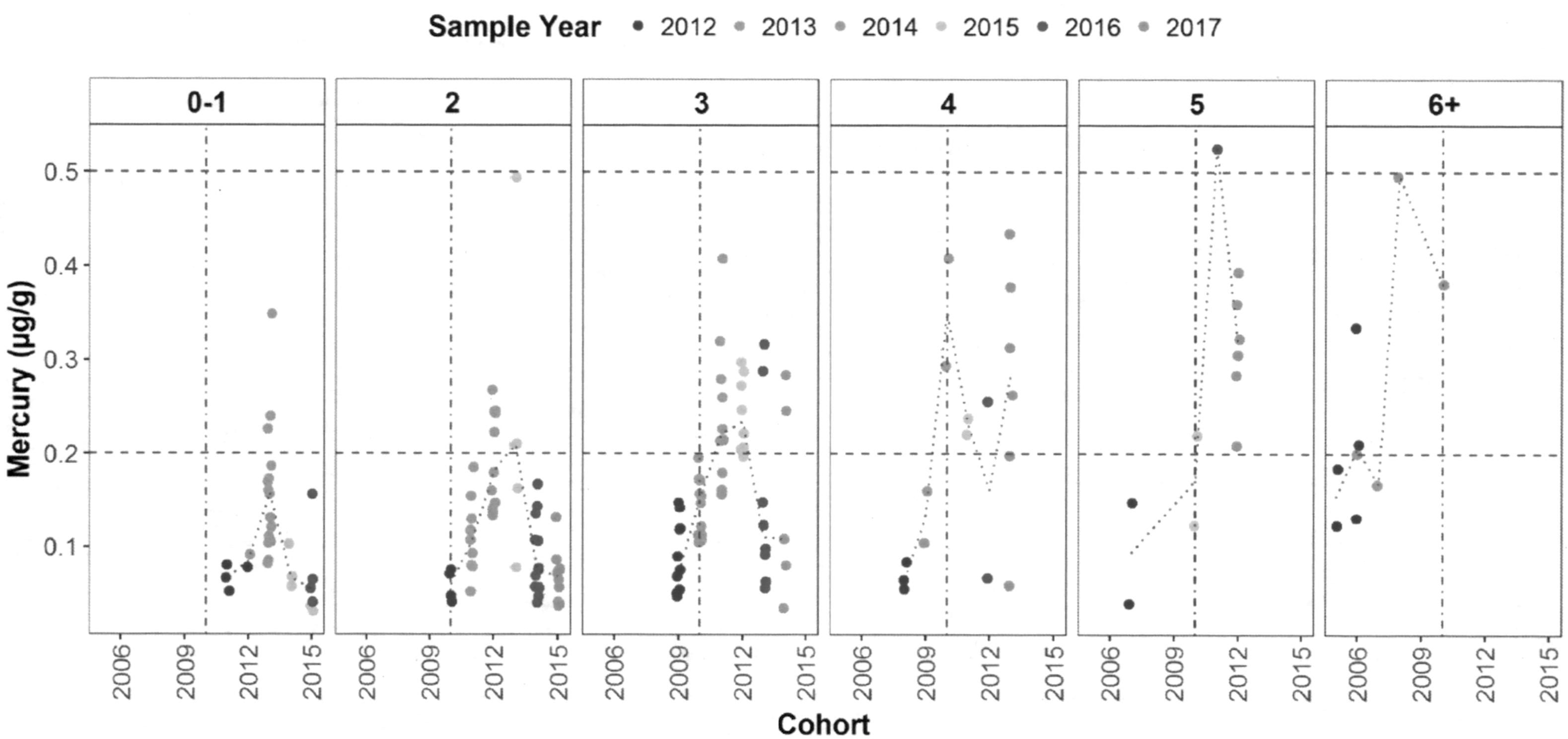
Table 3.4 Northern pike tissue mercury concentrations, 2012 to 2017.

		Tissue Mercury Concentration (µg/g)				
Year	**N**	**Min**	**Median**	**Max**	**Mean**	**S.D.**
2012	31	0.040	0.076	0.59	0.11	0.11
2013	26	0.053	0.130	0.20	0.13	0.040
2014	57	0.083	0.180	0.41	0.20	0.073
2015	23	0.031	0.210	0.49	0.18	0.11
2016	29	0.041	0.078	0.53	0.12	0.11
2017	30	*0.034*	*0.165*	*0.50*	*0.20*	*0.14*

Note: 2017 tissue mercury concentrations are as total methyl-mercury, whereas measurements from 2012 to 2016 were measured as total mercury. See Section 3.2.4.

Mercury concentrations in fish increase with age, as they feed and bioaccumulate mercury in their tissues. The accumulation of mercury in pike tissues can be assessed by analyzing the mercury concentration by each age-class across the cohorts of fish (i.e., the year of birth). Mercury is naturally excreted by organisms, so observed accumulation of mercury in tissues is the result of mercury intake minus excreted mercury. Figure 3.9 shows the tissue mercury concentrations for each fish presented by its cohort, which was calculated as the year of capture minus its age. Fish in cohorts prior to 2010 were born outside of Jackpine Lake and migrated into the Lake at some point prior to capture. Mercury accumulation would be observed as increases in tissue concentrations within an age-class across cohorts. A distinct peak-shaped pattern was observed in Jackpine Lake fish in the 0-1, 2, and 3-year age-classes (Figure 3.9). Age 2 fish from the 2012 and 2013 cohorts had significantly higher tissue mercury concentrations (Appendix A5). Similarly, the age 3 fish from the 2012 cohort had significantly higher tissue concentrations. These cohort-dependent relationships remained evident when adjusting for fish weight. In the early stages of commissioning, young pike in Jackpine Lake may have accumulated mercury at a greater rate, resulting in higher mercury concentrations in the 2012 and 2013 cohorts. However, fish in later cohorts (i.e., 2014 and 2015) have mercury concentrations similar to individuals from cohorts that originated outside of Jackpine Lake (i.e., age-classes 2 and 3). These patterns suggest that fish accumulated mercury at a greater rate during the initial years of Jackpine Lake, but accumulation has decreased and in 2017 was similar to the accumulation observed for fish originating outside of Jackpine Lake. This interpretation assumes that fish are resident in Jackpine Lake and these patterns are not confounded by immigration and emigration. Older fish do not appear to be accumulating mercury at increased rates in recent years, although the number of observations is limited. Continued monitoring will help to verify whether the accumulation of mercury in younger fish remains lower than the initial post-commissioning peak, as well as provide additional observations of older fish to more fully characterize the accumulation of mercury.

Figure 3.9 **Tissue mercury concentrations by age-class in northern pike cohorts captured in Jackpine Lake, 2012 to 2017.**



Cohort defined as the sampling year minus the age of sampled fish.
Each panel shows northern pike divided by age-class at the time of mercury sampling.
Cohort values are jittered to aid in visualization of overlapping points.
Median mercury values for each cohort by age class are shown by the dotted line.
Dashed lines show Health Canada's guidelines for human consumption for general consumers (0.5 µg/g) and subsistence fishers (0.2 µg/g).
Cohorts born prior to the establishment of Jackpine Lake are shown to the left of the vertical dot-dash line.
Mercury was measured as methyl-mercury in 2017, and total mercury in previous years.

3.2.4 Fish Component Quality Assurance and Quality Control Results

The fish component included a variety of quality control procedures that provide incremental checks and balances throughout data collection, data analysis, and reporting. Detailed field records of fish capture and processing were kept. All field metadata and data were reviewed and transcribed into electronic data records. Detailed descriptions of the QA/QC procedures specific to the fish component are provided in Appendix A1.

As noted in Section 2.3.3, the fish tissue collected in 2017 was analyzed for total methyl-mercury, rather than total mercury. The total methyl-mercury concentrations were considered directly comparable to total mercury concentrations because approximately 100% of the measured mercury in fish tissue is in the form of methyl-mercury (Bloom 1992, Duffy et al. 1999, Jackson 1990, Jewett et al. 2003, Lasorsa and Allen-Gill, 1995), and consequently no correction factor was applied. The primary uncertainty that results from the difference in analytes is a potential negative bias in the 2017 tissue concentrations. The reported mercury concentrations for the 2017 samples may be underestimates of the total mercury concentrations. The reported range of methyl-mercury to total mercury ratios is 0.90 to 1.03, which suggests the maximum degree of underestimation may be up to 10%. This bias is relatively small compared to the variation observed in fish tissue mercury concentrations, even when standardized by age-class (Figure 3.9).

4.0 SUMMARY

The 2017 assessment was conducted as planned, except for the analysis of northern pike tissue for methyl-mercury rather than total mercury. No other data quality or deviations were noted. The results of the 2017 program are summarized in Table 4.1.

Jackpine Lake continues to develop as a functioning aquatic ecosystem. Although hydrocarbons and PAH are measurable in the sediments, environmental quality indicators and toxicity assays show the sediment environment is suitable for supporting a diverse community of aquatic invertebrates. A stable population of northern pike continue to live and grow in Jackpine Lake, and one individual recaptured in 2017 had increased six-fold in weight since 2012. Median pike tissue mercury concentrations have decreased since 2014, and there is evidence that the accumulation of mercury in pike has decreased since the 2011-2014 monitoring period.

Table 4.1 Summary of the 2017 Jackpine Lake Monitoring Program.

	Results	Environmental Guidelines (if applicable)	Observed Trends
Fish Capture	Fish captured by electrofishing and angling along margins of Jackpine Lake. Recapture of two fish tagged in 2012.	-	No trends in fish capture noted. Change in focus of program in 2017.
Fish Condition	Fish condition metrics consistent with previous years. Long term monitoring program (2016 onwards) focused on larger fish for tissue analysis, which altered the distribution of captured fish lengths/weights	-	Fish condition consistent since 2010, which suggests growth and development of northern pike has not changed substantially
Mercury Analysis	Age-dependent tissue mercury concentrations: older fish had higher concentrations; younger fish had lower concentrations	Majority of fish captured in 2017 had mercury concentrations less than Health Canada guideline for subsistence fishers.	The accumulation of mercury in younger fish appears to be lower in the 2016-2017 period than was observed between 2011 and 2014.
Sediment Chemistry	Hydrocarbons and PAH continue to be measurable in sediments. Large increase in predicted PAH toxicity at JCL-2 attributed to decrease in overall hydrocarbon concentration.	Metal concentrations consistently less than guidelines for the protection of aquatic life. Some hydrocarbon (i.e., F3 analyte) and PAH analytes (i.e., acenapthene, chrysene, and phenanthrene) had concentrations greater than ISQG. No measurements of concentrations greater than PEL.	Concentrations of fine particles (i.e., silt and clay), organic matter, and metals greater than or near maximum values observed in previous years. Sediment hydrocarbon and PAH concentrations consistent with previous years; decreased concentrations at littoral site.
Sediment Toxicity	No significant effects on the survival of aquatic invertebrates. Decreased growth resulting from exposure to JCL-2 (southern lake) sediments.	-	Overall decreasing trend in toxicity, as measured by effects to growth.

REFERENCES

[AESRD] Alberta Environment and Sustainable Resource Development. 2014. Environmental Quality Guidelines for Alberta Surface Waters. Available from: http://esrd.alberta.ca/water/education-guidelines/surface-water-quality-guidelines-and-objectives.aspx

[CCME] Canadian Council of Ministers of the Environment. 1995. Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. CCME EPC-98E.

CCME. 2011. Sediment quality guidelines for the protection of freshwater aquatic life. Summary of existing Canadian Environmental Quality Guidelines. Available from: http://www.ccme.ca/publications/ceqg_rcqe.html

Blackwell BG, Brown ML, Willis DW. 2000. Relative Weight (Wr) Status and Current Use in Fisheries Assessment and Management. Rev. Fish. Sci. 8(1): 1-44.

Bloom NS. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 49: 1010-1017.

Duffy LK, Scofield E, Rogers T, Patton M, Bowyer RT. 1999. Comparative baseline levels of mercury, Hsp70 and Hsp60 in subsistence fish from the Yukon-Kuskokwim delta region of Alaska. Comp. Biochem. Physiol. 124C: 181-186.

[Hatfield] Hatfield Consultants. 2010. Evaluating Aquatic Habitat Loss and Compensation Offsets in the Athabasca Oil Sands. Prepare on behalf of Shell Canada Energy.

Jackson TA. 1990. Biological and environmental control of mercury accumulation by fish in lakes and reservoirs of Northern Manitoba, Canada. Can. J. Fish. Aquat. Sci. 48: 2449-2470.

Jewett SC, Zhang X, Naidu AS, Kelley JJ, Dasher D, Duffy LK. 2003. Comparison of mercury and methylmercury in northern pike and arctic grayling from western Alaska rivers. Chemosphere 50: 383-392.

Larosa B, Allen-Gill S. 1995. The methylmercury to total mercury ratio in selected marine, freshwater, and terrestrial organisms. Water Air Soil Poll. 80: 905-913.

MacKay WC, Ash GR, Norris HJ (eds.). 1990. Fish Ageing Methods for Alberta. RL&L Environmental Services Ltd., in association with Alberta Fish and Wildlife Division and University of Alberta. Edmonton, AB.

Mackay D, Shiu WY, Ma KC. 1992. Illustrated handbook of physical-chemical properties and environmental fate for organic chemicals. Polynuclear aromatic hydrocarbons, polychlorinated dioxins, and dibenzofurans. Chelsea (MI), USA: Lewis. 597 p.

Neff JM, Burns WA. 1996. Estimation of polycyclic aromatic hydrocarbon concentrations in the water column based on tissue residues in mussels and salmon: An equilibrium partitioning approach. Environ Toxico Chem 15:2240-2253.

Neff JM, Stout SA, Gunster DG. 2004. Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Sediments: Identifying Sources and Ecological Hazard. Integrated Environmental Assessment and Management 1:22-33.

Ran Y, He Y, Yang G, Johnson JLH, Yalkowsky SH. 2002. Estimation of aqueous solubility of organic compounds by using the general solubility equation. Chemosphere 48:487-509.

Willis DW. 1989. Proposed standard length-weight equation for northern pike. N. Am. J. Fish. Manage. 9(2): 203-208.

APPENDICES

Appendix A1

Quality Assurance and Quality Control (QA/QC)

A1.1 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

Quality assurance and quality control (QA/QC) for the Jackpine Lake Long-term Monitoring Program (the Program) consisted of a system of processes and controls to support the collection of high-quality data. The objective of this system is to provide assurance that defined standards of quality are being achieved. Quality control refers to the specific methodological techniques that are implemented within the quality assurance plan. The QA/QC program supports the collection and analysis of scientifically defensible and reproducible field and analytical data. The QA/QC procedures for the 2017 Program assessments consisted of the following components that were applied through the field sampling, data analysis, and reporting:

- Adherence to standard operating procedures (SOPs) for field data and sample collection, data transcription, data QA/QC, and record-keeping;
- Program-specific field work instructions (FWI) that provide detailed descriptions of the Program;
- Record-keeping using standardized forms, including catch records and chain-of-custody forms, as well as descriptive field notes; and
- Extensive analytical laboratory QA/QC procedures.

Hatfield maintains SOPs for field data collection activities to standardize approaches used by all Hatfield personnel. These documents identify specific methods for sample collection, sample labeling and handling, equipment calibration and use, and record-keeping. All Hatfield field technicians are trained and experienced with the SOPs and implement field programs according to the instructions presented within them.

In advance of each sampling program, an FWI was provided to and reviewed by each crew member. These documents consist of a detailed description of the sampling tasks to be undertaken and the rationale for collecting the data. A pre-field meeting was held by the project manager before each sampling program to review the FWI. This approach allowed any discrepancies in understanding to be identified and addressed prior to the start of sampling. Quality control procedures for data entry included a 100% re-check on all hardcopy data, to ensure accurate transcription from field data sheets to digital formats. Data were also displayed graphically to visually assess for the presence of any outliers caused by field data entry errors.

A1.1.1 Sediment Quality QA/QC

QA/QC procedures were followed for the collection of sediment to maintain data quality and prevent sediment sample contamination. Before sample collection, all equipment (i.e., spoons, pans, grabs) were cleaned using four steps:

1. Equipment was cleaned with ambient water and a metals-free soap (i.e., Liquinox);
2. Equipment was rinsed with environmental grade hexane;

3. Equipment was rinsed with environmental grade acetone (steps 2 and 3 remove any organic residues); and

4. Equipment was rinsed three times with ambient water.

Only grab samples that did not contain foreign objects, obtained an adequate penetration depth, and were not overfilled or leaking were retained. Sediments were transferred directly from the grab to a pan, where they were homogenized with a large spoon. All sampling equipment that came in direct contact with the sample was constructed from stainless steel. As an additional precaution, staff wore powder-free nitrile gloves throughout the equipment cleaning and sample collection process.

A1.1.2 Sediment Toxicity QA/QC

In 2017, all sediment toxicity testing was conducted by Maxxam Analytics. Each sample was taken from homogenized sediment collected using the sediment quality QA/QC procedures outlined in Section A1.1. The toxicological laboratories used a number of laboratory QA/QC procedures to ensure that the reported results for both sediment and water toxicity tests were precise and accurate. For each set of tests, a control group and reference toxicant were used to assess the accuracy of the toxicity test. In addition, five replicates of each treatment group were used in each test, to assess the precision of the results. All laboratory QA/QC sample results were reviewed using in-house laboratory protocols to assess potential contamination and the precision and accuracy of the analyses. Any deviations from QA/QC criteria were identified in the laboratory reports.

A1.1.3 Fish QA/QC

Fish ageing results reported by North/South Consultants included a re-analysis of a subset of ageing structures and both the initial and QA/QC ages were reported (Appendix A4). Quality control was undertaken by an alternate ageing technician on approximately 10% of randomly selected structures. The QA/QC readings were also conducted "blind" to determine consistency and accuracy. A description of the confidence index rating is provided in Table A1.1.

Data were received in electronic format (Microsoft Excel©) from the analytical laboratory. All data were checked for transcription errors or other inconsistencies. Data analysis was conducted using duplicate data files for processing. Original data were retained in back-up files for the Program.

The fish tissue data reports issued by Flett Research Ltd. (Flett) included a description of the laboratory's internal quality procedures. QC procedures used by Flett included laboratory duplicates, spike samples, calibration control, and use of certified reference and internal standards. Where relevant, comments on the results of the analyses were indicated on the data reports (Appendix A4).

Data were received in electronic format (Microsoft Excel©) from the analytical laboratory. All data were checked for transcription errors or other inconsistencies. Data analysis was conducted using duplicate data files for processing. All original data were retained in back-up files.

Table A1.1 Fish Aging Quality Control Criteria

Confidence Indices and Abbreviations	Qualitative characteristics (pattern clarity)	Quantitative characteristics (repeatability)
Very Good (VG)	annuli are clear with no interpretation problems	Reader always gets the same age
Good (G)	annuli are clear with a few easy interpretation problems	Reader would get the same age most of the time for fish <10 years, within one year for fish 11-20 years
Fair (F)	annuli are fairly clear with some areas presenting easy and moderate interpretation problems	Reader would be within 1 year most of the time for fish<10 years and 2-3 years for fish >10 years
Poor (P)	annuli are fairly unclear presenting a number of difficult interpretation problems	Reader would be within 2-3 years most of the time for fish <10 years and 4-5 years for fish >10 years
Very Poor (VP)	annuli are very unclear presenting significant interpretation problems	Reader has little confidence in repeatability of age within 4-5 years

A1.2 QA/QC RESULTS

A1.2.1 Sediment Quality

The sediment quality samples were collected in adherence to the SOP and FWI and were analyzed by accredited analytical laboratories. Chain-of-custody forms were complete and are included in Appendix A2.1.

The sediment quality analyses for particle size analyses, metals, and hydrocarbons by ALS Environmental incorporated the following analytical laboratory data quality measures (Appendix A2.1):

- laboratory duplicates;
- laboratory control samples;
- method blanks;
- matrix spikes; and
- internal and certified reference materials.

The detection limits for the F2, F3, and F4 hydrocarbon analytes were adjusted because of high moisture content; however, the measurements for those analytes were substantially greater than the reported detection limits, so no data quality concerns were noted.

The analysis of sediment for PAH by SGS AXYS incorporated the following analytical laboratory data quality measures (Appendix A2.1):

- labeled compound spikes;
- calibration relative responses and ion abundance ratios; and
- calibration verification measurements.

No data quality flags were identified in the analytical reports, with the exception of measurements less than analytical detection limits and measurements less than the analytical quantification limits.

Adherence to the SOP and conformance to the laboratory QA/QC protocols resulted in the conclusion that the sediment quality data met the data quality objectives for the Program.

A1.2.2 Sediment Toxicity

The sediment toxicity samples were collected in adherence to the SOP and FWI and were analyzed by accredited analytical laboratories. Chain-of-custody forms were complete and are included in Appendix A2.2. Sediment samples were analyzed for total organic carbon and moisture, and those measurements met the analytical laboratory data quality objectives for method blanks and laboratory duplicates. The sediment collected for the toxicity assays was similar in total organic carbon (TOC) and moisture to the samples analyzed for sediment physico-chemical properties (Table A2.1).

Table A1.2 Comparison of sediment characteristics between sediment quality and sediment toxicity samples, 2017.

Analyte	JCL-1		JCL-2	
	SQ	Toxicity	SQ	Toxicity
Moisture	65	62	41	38
TOC	11	9.3	3	2.7

The sediment samples were received by the ecotoxicology laboratory within one week of collection in 2017. All toxicity assays were started within the sampling holding limits. The toxicity assays met the following data quality objectives:

- Mean percent survival in the negative control greater than 70% (*Chironomus*) or 80% (*Hyalella*);
- Mean dry weight of *Chironomus* larvae was greater than 0.6 mg, and the dry weight of *Hyalella* was greater than 0.1 mg per organism; and
- Reference toxicant LC50 within 2 standard deviations of the historic mean LC50.

The method deviations were concluded to have minimal effects on the results. The use of a single container would not likely result in biases in the results, since the sediment was homogenized prior to the assay. The pupated individuals were still included in the survival endpoint.

Adherence to the SOP and conformance to the laboratory QA/QC protocols resulted in the conclusion that sediment toxicity data met the data quality objectives for the program.

A1.2.3 Fish

The confidence indices of all fish ageing structures analyzed in 2017 were graded Fair or better (Appendix A4). The majority of fish ageing structures in 2017 were graded Fair, with 8 of 30 rays graded Good. Ten percent of structures aged were independently analyzed by a second analyst (i.e., 3 samples in 2017). The estimated ages were the same between analysts for all reanalyzed fin rays in 2017. Therefore, the fish age data were concluded to meet the data quality objectives for the program.

Northern pike tissue plugs were collected in adherence to the SOP and FWI and analyzed by an accredited analytical laboratory (Flett Research Ltd.). As noted in Section 2.3.3, the fish tissue samples in 2017 were erroneously analyzed for methyl-mercury, rather than total mercury. This error was the result of an incorrect code on the chain-of-custody form that was not corrected prior to sample analysis.

No data quality issues were noted for the analysis of tissue mercury. The analytical laboratory QA/QC process included bubbler and method blanks, calibration standards, matrix spikes, reference material, and ongoing process and recovery material to monitor data quality throughout the analysis. The relative percent differences of laboratory duplicates were less than 10% (i.e., 8.8%, 0.9%, and 1.0% in 2017).

The fish ageing and tissue total mercury data were concluded to meet the data quality objectives of the program because of adherence to the SOP and the results of laboratory QA/QC. The 2017 tissue mercury concentrations should be interpreted with caution because of the change in analytical methodology, although almost all mercury present in northern pike tissue is in the form of methyl-mercury (Section 2.3.3).

Appendix A2

Sediment Quality Data

Table A2.1 Sediment Quality Analytical Results, 2017.

Analyte	Units	DL/RL	JCL-1	JCL-2	LIT-1
Physical Variables					
% Moisture	%	0.50	64.6	40.7	50.6
% Clay (<2um)	%	1	13.4	23.8	6.8
% Sand (2.0mm - 0.05mm)	%	1	16.6	59	70.2
% Silt (0.05mm - 2um)	%	1	70	17.2	23
Texture			Silt loam	Sandy clay loam	Sandy loam
Metals					
Aluminum (Al)	mg/kg	50	5860	5300	2210
Antimony (Sb)	mg/kg	0.1	<0.10	0.12	<0.10
Arsenic (As)	mg/kg	0.1	3.1	2.04	1.26
Barium (Ba)	mg/kg	0.5	82.8	49.9	36.5
Beryllium (Be)	mg/kg	0.1	0.39	0.34	0.15
Bismuth (Bi)	mg/kg	0.2	<0.20	<0.20	<0.20
Boron (B)	mg/kg	5	11.1	6	6.5
Cadmium (Cd)	mg/kg	0.02	0.164	0.063	0.063
Calcium (Ca)	mg/kg	50	12900	4390	4310
Chromium (Cr)	mg/kg	0.5	11	9.56	4.56
Cobalt (Co)	mg/kg	0.1	6.15	3.81	2.14
Copper (Cu)	mg/kg	0.5	8.66	6.09	3.04
Iron (Fe)	mg/kg	50	15600	10500	6500
Lead (Pb)	mg/kg	0.5	5.87	4.29	2.12
Lithium (Li)	mg/kg	2	6.8	5.3	<2.0
Magnesium (Mg)	mg/kg	20	3570	2240	1150
Manganese (Mn)	mg/kg	1	489	196	335
Mercury (Hg)	mg/kg	0.005	0.0357	0.0178	0.0129
Molybdenum (Mo)	mg/kg	0.1	0.5	0.35	0.26
Nickel (Ni)	mg/kg	0.5	12.4	8.77	4.99
Phosphorus (P)	mg/kg	50	517	261	215
Potassium (K)	mg/kg	100	830	780	380
Selenium (Se)	mg/kg	0.2	0.25	<0.20	<0.20
Silver (Ag)	mg/kg	0.1	<0.10	<0.10	<0.10
Sodium (Na)	mg/kg	50	170	90	72
Strontium (Sr)	mg/kg	0.5	41.7	21.4	20.4
Sulfur (S)	mg/kg	1000	6800	1600	1400
Thallium (Tl)	mg/kg	0.05	0.088	0.072	<0.050
Tin (Sn)	mg/kg	2	<2.0	<2.0	<2.0
Titanium (Ti)	mg/kg	1	34.2	50.9	31.9
Tungsten (W)	mg/kg	0.5	<0.50	<0.50	<0.50
Uranium (U)	mg/kg	0.05	0.847	0.411	0.309
Vanadium (V)	mg/kg	0.2	19.6	16.7	7.96
Zinc (Zn)	mg/kg	2	40.5	19.6	13
Zirconium (Zr)	mg/kg	1	7.6	7.9	2.3
Total Petroleum Hydrocarbons					
F1 (C6-C10)	mg/kg	10	11	12	<10
F1-BTEX	mg/kg	10	11	12	<10
F2 (C10-C16)	mg/kg	40; 20; 20	110	36	20
F3 (C16-C34)	mg/kg	40; 20; 20	1500	293	580
F4 (C34-C50)	mg/kg	40; 20; 20	1160	197	484
F4G-SG (GHH-Silica)	mg/kg	500	6920	1330	3320
Total Hydrocarbons (C6-C50)	mg/kg	-	-	-	-
1,4-Difluorobenzene (SS)	%	1	90.4	91.9	76.9
3,4-Dichlorotoluene (SS)	%	1	86.5	81.7	74.1
4-Bromofluorobenzene (SS)	%	1	85.7	90.1	71.2
Benzene	mg/kg	0.005	0.013	<0.0050	<0.0050
Ethylbenzene	mg/kg	0.01	0.015	<0.010	<0.010

Table A2.1 (Cont'd.)

Analyte	Units	DL/RL	JCL-1	JCL-2	LIT-1
Total Petroleum Hydrocarbons (cont'd.)					
m+p-Xylene	mg/kg	0.05	<0.050	<0.050	<0.050
o-Xylene	mg/kg	0.05	<0.050	<0.050	<0.050
Styrene	mg/kg	0.05	<0.050	<0.050	<0.050
Toluene	mg/kg	0.05	<0.050	<0.050	<0.050
Xylenes	mg/kg	0.1	<0.10	<0.10	<0.10
2-Bromobenzotrifluoride	%	1	82.3	81.2	78.9
Total Carbon					
Inorganic Carbon (as $CaCO_3$ Equivalent)	%	0.4	3.03	1.28	1.32
Total Carbon by Combustion	%	0.05	11.7	3.32	4.42
Inorganic Carbon	%	0.05	0.364	0.154	0.159
Total Organic Carbon	%	0.05	11.3	3.17	4.26
PAHs					
Naphthalene	ng/g	0.055; 0.123; 0.097	1.79	1.22	1.19
Acenaphthylene	ng/g	0.113; 0.094; 0.062	0.274 (NDR)	0.387 (NDR)	0.179 (NDR)
Acenaphthene	ng/g	0.09; 1.97; 0.092	6.28	16.2	0.765
2-Methylfluorene	ng/g	0.88; 1.36; 0.268	4.65	5.05	0.542
C2 Phenanthrenes/Anthracenes	ng/g	1.98; 3.63; 0.414	462	913	79.5
Fluorene	ng/g	0.313; 0.2; 0.076	3.86	3.02	0.628
Phenanthrene	ng/g	1.19; 3; 0.257	51.8	96.4	7.67
Anthracene	ng/g	1.16; 2.94; 0.251	ND	ND	0.536 (NDR)
C1 Phenanthrenes/Anthracenes	ng/g	0.794; 1.96; 0.734	242	452	34
Fluoranthene	ng/g	1.68; 2.12; 0.482	6.78	11.3	1.61
Pyrene	ng/g	1.61; 2.03; 0.461	33.4	36.2	9.18
Benz[a]anthracene	ng/g	1.95; 1.83; 0.331	12	17.2	2.1 (NDR)
Chrysene	ng/g	2.24; 2.05; 0.366	106	116	29.3
Benzo[b]fluoranthene	ng/g	2.72; 2.19; 0.85	21.5	20.8	6.19
Benzo[j,k]fluoranthenes	ng/g	2.62; 2.2; 0.837	7.45	6.25	1.63 (NDR)
Benzo[e]pyrene	ng/g	3.83; 3.15; 1.13	53.4	46.2	24.7
Benzo[a]pyrene	ng/g	3.7; 3.05; 1.09	10.5	13.6	3.54
Perylene	ng/g	3.67; 3; 0.998	85	48.9	19.7
Dibenz[a,h]anthracene	ng/g	1.76; 0.967; 0.862	6.16	5.34	3.68
Indeno[1,2,3-cd]pyrene	ng/g	1.89; 1.36; 1.38	15.4	10.2	6.85
Benzo[ghi]perylene	ng/g	1.69; 1.26; 1.01	32.5	23.7	24.5
2-Methylnaphthalene	ng/g	0.091; 0.097; 0.074	2.41	1.4	1.32
1-Methylnaphthalene	ng/g	0.099; 0.104; 0.08	2.04	1.12	0.806
C1-Naphthalenes	ng/g	0.091; 0.097; 0.074	4.46	2.53	2.12
Biphenyl	ng/g	0.036; 0.193; 0.046	1.44	0.892	0.647
C1-Biphenyls	ng/g	0.136; 0.175; 0.046	1.84	2.52	1.07
C2-Biphenyls	ng/g	2.6; 0.16; 0.045	8.99	12.5	1.84
C2-Naphthalenes	ng/g	0.123; 0.149; 0.157	17.4	19.6	6.13
1,2-Dimethylnaphthalene	ng/g	0.123; 0.149; 0.157	2.1 (NDR)	2.77 (NDR)	0.488
2,6-Dimethylnaphthalene	ng/g	0.105; 0.127; 0.134	3.26	2.43 (NDR)	1.4
C3-Naphthalenes	ng/g	1.06; 1.02; 0.183	104	143	13.7
2,3,6-Trimethylnaphthalene	ng/g	1.02; 0.98; 0.175	22.1	23.3	3.23
2,3,5-Trimethylnaphthalene	ng/g	1.11; 1.07; 0.191	16.1	17.6	2.19
C4-Naphthalenes	ng/g	3.3; 13; 0.239	252	686	21.8
C1-Acenaphthenes	ng/g	0.098; 0.263; 0.123	ND	ND	ND
C1-Fluorenes	ng/g	0.88; 1.36; 0.268	43.2	79.5	5.95
1,7-Dimethylfluorene	ng/g	1.56; 2.31; 0.413	61.1	109	4.34
C2-Fluorenes	ng/g	1.56; 2.31; 0.413	346	634	25.4
C3-Fluorenes	ng/g	4.05; 5.02; 0.791	761	1400	102
Dibenzothiophene	ng/g	1.46; 2.84; 0.379	6.17 (NDR)	7.45 (NDR)	1.41 (NDR)
C1-Dibenzothiophenes	ng/g	0.784; 4.99; 0.616	90	64.4	14.6
2/3-Methyldibenzothiophenes	ng/g	0.784; 4.99; 0.616	31.9	29	5.11

Table A2.1 (Cont'd.)

Analyte	Units	DL/RL	JCL-1	JCL-2	LIT-1
PAHs (cont'd.)					
C2-Dibenzothiophenes	ng/g	2.63; 3.83; 0.305	838	1610	124
2,4-Dimethyldibenzothiophene	ng/g	2.63; 3.83; 0.305	44.2	95.3	6.91 (NDR)
C3-Dibenzothiophenes	ng/g	1.84; 5.62; 0.494	2110	3640	302
C4-Dibenzothiophenes	ng/g	4.07; 5.05; 1.29	2050	2890	310
3-Methylphenanthrene	ng/g	0.832; 2.06; 0.769	50.5	83.8	6.72
2-Methylphenanthrene	ng/g	0.832; 2.06; 0.769	50.4	100	7.47
2-Methylanthracene	ng/g	0.864; 2.14; 0.799	2.66 (NDR)	9.1 (NDR)	ND
9/4-Methylphenanthrene	ng/g	0.832; 2.06; 0.769	89.3	174	12.7
1-Methylphenanthrene	ng/g	0.794; 1.96; 0.734	51.5	94.9	7.08
3,6-Dimethylphenanthrene	ng/g	2; 3.67; 0.418	44.3 (NDR)	78.4 (NDR)	5.73 (NDR)
2,6-Dimethylphenanthrene	ng/g	1.98; 3.63; 0.414	21.4	36	4.61 (NDR)
1,7-Dimethylphenanthrene	ng/g	1.96; 3.6; 0.41	54.1	102	11.3
1,8-Dimethylphenanthrene	ng/g	1.98; 3.63; 0.414	24.8	43.6	3.3
C3-Phenanthrenes/Anthracenes	ng/g	1.62; 5.44; 0.988	636	1360	132
1,2,6-Trimethylphenanthrene	ng/g	1.62; 5.44; 0.988	33.3 (NDR)	72.5 (NDR)	5.2 (NDR)
Retene	ng/g	5.06; 7.01; 1.62	178 (NDR)	185 (NDR)	19.3 (NDR)
C4-Phenanthrenes/Anthracenes	ng/g	5.06; 7.01; 1.62	2030	2260	381
C1-Fluoranthenes/Pyrenes	ng/g	1.14; 4.45; 1.63	464	537	17
3-Methylfluoranthene/Benzo[a]fluorene	ng/g	1.14; 4.45; 1.63	78.6	162	17.9
C2-Fluoranthenes/Pyrenes	ng/g	1.49; 2.86; 0.646	1050	1230	301
C3-Fluoranthenes/Pyrenes	ng/g	3.68; 3.1; 1.09	936	879	332
C4-Fluoranthenes/Pyrenes	ng/g	2.76; 2.15; 1.98	432	468	164
C1-Benzo[a]anthracenes/Chrysenes	ng/g	3.38; 3.81; 1.14	355	398	71.6
5/6-Methylchrysene	ng/g	3.52; 3.97; 1.18	32.3	40.9	4.72
1-Methylchrysene	ng/g	3.25; 3.67; 1.09	34.3	42.5	5.98
C2-Benzo[a]anthracenes/Chrysenes	ng/g	1.84; 1.47; 0.733	511	596	132
5,9-Dimethylchrysene	ng/g	1.84; 1.47; 0.733	109	97.8	25.4
C3-Benzo[a]anthracenes/Chrysenes	ng/g	3.86; 1.43; 0.96	130	244	55
C4-Benzo[a]anthracenes/Chrysenes	ng/g	2.07; 4.37; 0.776	122	114	40.4
C1-Benzofluoranthenes/Benzopyrenes	ng/g	2.4; 2.25; 0.976	266	218	110
7-Methylbenzo[a]pyrene	ng/g	2.4; 2.25; 0.976	21.4	21.8	9.77
C2-Benzofluoranthenes/Benzopyrenes	ng/g	2.87; 19.6; 1.28	219	164	72.2
1,4,6,7-Tetramethylnaphthalene	ng/g	3.3; 13; 0.239	42.1 (NDR)	142 (NDR)	4.23 (NDR)
% Moisture	%	-	61.5	30.5	36.4
Naphthalene d-8 (% Recovery)	%	-	53.2	38.4	26.7
2-Methylnaphthalene d-10 (% Recovery)	%	-	66.8	56.1	33
Biphenyl d-10 (% Recovery)	%	-	71.3	66.2	37.5
2,6-Dimethylnaphthalene d-12 (% Recovery)	%	-	74.2	69.4	38.9
Acenaphthylene d-8 (% Recovery)	%	-	72.5	70.7	38.3
Dibenzothiophene d-8 (% Recovery)	%	-	70.8	72.9	39.4
Phenanthrene d-10 (% Recovery)	%	-	72	77.7	44
Fluoranthene d-10 (% Recovery)	%	-	94.5	99.6	51
Benzo[a]anthracene d-12 (% Recovery)	%	-	87.5	87.7	54.7
Chrysene d-12 (% Recovery)	%	-	83.3	83.2	53.1
Benzo[b]fluoranthene d-12 (% Recovery)	%	-	82.5	86.4	50
Benzo[k]fluoranthene d-12 (% Recovery)	%	-	77	80.7	48.7
Benzo[a]pyrene d-12 (% Recovery)	%	-	75.5	77.4	50.3
Perylene d-12 (% Recovery)	%	-	80.7	81.5	57.5
Dibenzo[a,h]anthracene d-14 (% Recovery)	%	-	83.8	77.5	50.8
Indeno[1,2,3-cd]pyrene d-12 (% Recovery)	%	-	78.6	77.4	53.4
Benzo[ghi]perylene d-12 (% Recovery)	%	-	78.5	74.3	70

ND = not detected at RL

NDR = peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration

Appendix A2.1

Analytical Sediment Quality Lab Reports

SGS AXYS

2045 Mills Road West
Sidney, BC, Canada V8L5X2

TEL: (250) 655-5800
TOLL-FREE: 1-888-373-0881

SGS AXYS Client No.: 2600

Client Address: Hatfield Consultants
200-850 Harbourside Drive
North Vancouver, BC, Canada, V7P 0A3

The SGS AXYS contact for these data is Georgina Brooks.

BATCH SUMMARY

Batch ID: WG61775	***Date:*** 07-Dec-2017
Analysis Type: PAH	***Matrix Type:*** Solid

BATCH MAKEUP

Contract: 2600

Samples:

L28178-1	JLC-1
L28178-2	JLC-2
L28178-3	LIT-1

Blank: WG61775-101

Reference or Spike: WG61775-102

Duplicate:

Comments:

1. Data are considered final.
2. Data are not blank corrected. Blank data should be taken into consideration when evaluating sample data.
3. Blank data should be evaluated against specifications using the same blank sample size as the size of the client samples.

www.axysanalytical.com

s.19(1)

AXYS | Axys Analytical Services Ltd

2045 Mills Road
Sidney, British Columbia, Canada V8L 5X2 TEL: (250) 655-5800 FAX: (250) 655-5811

CHAIN OF CUSTODY

2600 PB. 26-Oct-2017

AXYS CLIENT #: ~~2607~~

REPORT TO:		INVOICE TO:	
Company	HATFIELD CONSULTANTS	Company	
Address	200-850 Harbourside Dr. North Vancouver BC. V7P 0A3	Address	
Contact	Meghan Isaacs	Contact	Daisy Ngai
Phone	(604) 926-3261	Phone	604 926-3261
FAX	(604) 926-5389	FAX	
E-mail		E-mail	
Project Name/Number:	Shell 8642	Sampler's Name:	
		Signature:	

Client Sample Identification	Matrix	Sampling Date	Sampling Time	Container Type/No.	AXYS Lab Sample ID (Lab use only)	ANALYSIS REQUESTED				
JCL-1		OCT17/17	11:30	250mL	L28178-1	/				
JCL-2		OCT17/17	1345	250mL	-2	/				
LFT-1		OCT17/17	1300	250mL	-3	/				

Relinquished by (Signature)	Date	Time	Received by (Signature)	Date	Time
	Oct 23/2017			26-Oct-2017	10:15

Courier	Waybill No.

Remarks: Quote# Q6858

Sample Receipt

	Cooler
Temp °C	
Custody Seal #	
Seal Intact Y / N	
Sample Tags Y / N	

AXYS METHOD MLA-021 Rev 12

Form 1A
POLYAROMATIC HYDROCARBON ANALYSIS REPORT

CLIENT SAMPLE NO.
JLC-1
Sample Collection:
17-Oct-2017 11:30

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**Project No.**	SHELL 8642
Matrix:	SOLID	**Lab Sample I.D.:**	L28178-1
Sample Receipt Date:	26-Oct-2017	**Sample Size:**	13.9 g (dry)
Extraction Date:	10-Nov-2017	**Initial Calibration Date:**	18-Nov-2017
Analysis Date:	29-Nov-2017 **Time:** 14:21:00	**Instrument ID:**	LR GC/MS
Extract Volume (uL):	500	**GC Column ID:**	RTX5
Injection Volume (uL):	1.0	**Sample Data Filename:**	**PH7S6531.D**
Dilution Factor:	N/A	**Blank Data Filename:**	PH7S6503.D
		Cal. Ver. Data Filename:	PH7S6527.D
Concentration Units:	ng/g (dry weight basis)	**% Moisture:**	61.5

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
Naphthalene	91-20-3		1.79	0.055 (S)	0.08	1.006
Acenaphthylene	208-96-8	NDR	0.274	0.113 (S)	0.74	1.003
Acenaphthene	83-32-9		6.28	0.090 (S)	1.18	1.047
2-Methylfluorene	1430-97-3		4.65	0.880 (S)	1.02	0.938
C2 Phenanthrenes/Anthracenes			462	1.98 (S)		
Fluorene	86-73-7		3.86	0.313 (S)	1.04	0.844
Phenanthrene	85-01-8		51.8	1.19 (S)	0.18	1.004
Anthracene	120-12-7	ND		1.16 (S)		
C1 Phenanthrenes/Anthracenes			242	0.794 (S)		
Fluoranthene	206-44-0		6.78	1.68 (S)	0.23	1.002
Pyrene	129-00-0		33.4	1.61 (S)	0.18	1.032
Benz[a]anthracene [3]	56-55-3		12.0	1.95 (S)	0.24	1.002
Chrysene [4]	218-01-9		106	2.24 (S)	0.31	1.002
Benzo[b]fluoranthene	205-99-2		21.5	2.72 (S)	0.20	1.004
Benzo[j,k]fluoranthenes			7.45	2.62 (S)	0.23	1.002
Benzo[e]pyrene	192-97-2		53.4	3.83 (S)	0.23	0.996
Benzo[a]pyrene	50-32-8		10.5	3.70 (S)	0.20	1.004
Perylene	198-55-0		85.0	3.67 (S)	0.22	1.004
Dibenz[a,h]anthracene [5]	53-70-3		6.16	1.76 (S)	0.18	1.003
Indeno[1,2,3-cd]pyrene	193-39-5		15.4	1.89 (S)	0.21	1.002
Benzo[ghi]perylene	191-24-2		32.5	1.69 (S)	0.29	1.003
2-Methylnaphthalene	91-57-6		2.41	0.091 (S)	0.90	1.009
1-Methylnaphthalene	90-12-0		2.04	0.099 (S)	0.88	1.040
C1-Naphthalenes			4.46	0.091 (S)		
Biphenyl	92-52-4		1.44	0.036 (S)	0.32	1.005
C1-Biphenyls			1.84	0.136 (S)		
C2-Biphenyls			8.99	2.60 (S)		
C2-Naphthalenes			17.4	0.123 (S)		
1,2-Dimethylnaphthalene	573-98-8	NDR	2.10	0.123 (S)	2.60	1.082

s.19(1)

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
2,6-Dimethylnaphthalene	581-42-0		3.26	0.105 (S)	0.67	1.011
C3-Naphthalenes			104	1.06 (S)		
2,3,6-Trimethylnaphthalene	829-26-5		22.1	1.02 (S)	1.02	1.203
2,3,5-Trimethylnaphthalene	2245-38-7		16.1	1.11 (S)	1.06	1.226
C4-Naphthalenes			252	3.30 (S)		
C1-Acenaphthenes		ND		0.098 (S)		
C1-Fluorenes			43.2	0.880 (S)		
1,7-Dimethylfluorene	442-66-0		61.1	1.56 (S)	0.06	1.032
C2-Fluorenes			346	1.56 (S)		
C3-Fluorenes			761	4.05 (S)		
Dibenzothiophene	132-65-0	NDR	6.17	1.46 (S)	0.48	1.003
C1-Dibenzothiophenes			90.0	0.784 (S)		
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		31.9	0.784 (S)	0.69	1.094
C2-Dibenzothiophenes			838	2.63 (S)		
2,4-Dimethyldibenzothiophene	31317-18-7		44.2	2.63 (S)	0.48	1.162
C3-Dibenzothiophenes			2110	1.84 (S)		
C4-Dibenzothiophenes			2050	4.07 (S)		
3-Methylphenanthrene	832-71-3		50.5	0.832 (S)	0.69	1.088
2-Methylphenanthrene	2531-84-2		50.4	0.832 (S)	0.61	1.092
2-Methylanthracene	613-12-7	NDR	2.66	0.864 (S)	1.44	1.098
9/4-Methylphenanthrene	883-20-5/832-64-4		89.3	0.832 (S)	0.65	1.107
1-Methylphenanthrene	832-69-9		51.5	0.794 (S)	0.66	1.110
3,6-Dimethylphenanthrene	1576-67-6	NDR	44.3	2.00 (S)	1.12	0.969
2,6-Dimethylphenanthrene	17980-16-4		21.4	1.98 (S)	0.37	0.975
1,7-Dimethylphenanthrene	483-87-4		54.1	1.96 (S)	0.38	0.992
1,8-Dimethylphenanthrene	7372-87-4		24.8	1.98 (S)	0.43	1.006
C3-Phenanthrenes/Anthracenes			636	1.62 (S)		
1,2,6-Trimethylphenanthrene	30436-55-6	NDR	33.3	1.62 (S)	0.80	1.076
Retene	483-65-8	NDR	178	5.06 (S)	0.96	1.083
C4-Phenanthrenes/Anthracenes			2030	5.06 (S)		
C1-Fluoranthenes/Pyrenes			464	1.14 (S)		
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6		78.6	1.14 (S)	1.05	1.083
C2-Fluoranthenes/Pyrenes			1050	1.49 (S)		
C3-Fluoranthenes/Pyrenes			936	3.68 (S)		
C4-Fluoranthenes/Pyrenes			432	2.76 (S)		
C1-Benzo[a]anthracenes/Chrysenes [4]			355	3.38 (S)		
5/6-Methylchrysene	3697-24-3/1705-85-7		32.3	3.52 (S)		1.065
1-Methylchrysene	3351-28-8		34.3	3.25 (S)		1.073
C2-Benzo[a]anthracenes/Chrysenes [4]			511	1.84 (S)		
5,9-Dimethylchrysene	139493-40-6		109	1.84 (S)		1.127
C3-Benzo[a]anthracenes/Chrysenes [4]			130	3.86 (S)		
C4-Benzo[a]anthracenes/Chrysenes [4]			122	2.07 (S)		
C1-Benzofluoranthenes/Benzopyrenes			266	2.40 (S)		
7-Methylbenzo[a]pyrene	63041-77-0		21.4	2.40 (S)		1.108
C2-Benzofluoranthenes/Benzopyrenes			219	2.87 (S)		
1,4,6,7-Tetramethylnaphthalene	13764-18-6	NDR	42.1	3.30 (S)	0.11	1.377

(1) Where applicable, custom lab flags have been used on this report; ND = not detected at RL; NDR = peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration.
(2) Reporting Limit (Code): S = sample detection limit; M = method detection limit; L = lowest calibration level equivalent; Q = minimum reporting level.
(3) May co-elute with Cyclopenta(cd)pyrene.
(4) May co-elute with Triphenylene.
(5) May co-elute with Dibenz[a,c]anthracene.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest1A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_L28178-1_Form1A_PH7S6531.D_SJ2309855.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
JLC-1
Sample Collection:
17-Oct-2017 11:30

Form 2

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**Project No.**	SHELL 8642
		Lab Sample I.D.:	L28178-1
Matrix:	SOLID	**Sample Size:**	13.9 g (dry)
Sample Receipt Date:	26-Oct-2017	**Initial Calibration Date:**	18-Nov-2017
Extraction Date:	10-Nov-2017	**Instrument ID:**	LR GC/MS
Analysis Date:	29-Nov-2017 **Time:** 14:21:00	**GC Column ID:**	RTX5
Extract Volume (uL):	500	**Sample Data Filename:**	**PH7S6531.D**
Injection Volume (uL):	1.0	**Blank Data Filename:**	PH7S6503.D
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	PH7S6527.D
Concentration Units:	ng absolute	**% Moisture:**	61.5

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

LABELED COMPOUND	LAB FLAG [1]	SPIKE CONC.	CONC. FOUND	R(%) [2]	ION ABUND. RATIO	RRT
Naphthalene d-8		2000	1060	53.2	0.09	0.609
2-Methylnaphthalene d-10		2000	1340	66.8	0.17	0.755
Biphenyl d-10		2020	1440	71.3		0.868
2,6-Dimethylnaphthalene d-12		2020	1500	74.2	0.74	0.896
Acenaphthylene d-8		2000	1450	72.5	0.16	0.961
Dibenzothiophene d-8		2010	1420	70.8	0.10	0.791
Phenanthrene d-10		2010	1450	72.0	0.15	0.807
Fluoranthene d-10		2010	1890	94.5	0.17	0.970
Benzo[a]anthracene d-12		2000	1750	87.5	0.25	1.165
Chrysene d-12		2000	1670	83.3	0.26	1.170
Benzo[b]fluoranthene d-12		2020	1670	82.5	0.21	0.957
Benzo[k]fluoranthene d-12		2010	1540	77.0	0.18	0.961
Benzo[a]pyrene d-12		2010	1510	75.5	0.22	1.009
Perylene d-12		2010	1620	80.7	0.24	1.024
Dibenzo[a,h]anthracene d-14		2000	1680	83.8	0.24	1.209
Indeno[1,2,3-cd]pyrene d-12		2000	1570	78.6	0.15	1.205
Benzo[ghi]perylene d-12		2010	1570	78.5	0.19	1.236

(1) Where applicable, custom lab flags have been used on this report.
(2) R% = percent recovery.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________________

For Axys Internal Use Only [XSL Template: Pest2.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_L28178-1_Form2_PH7S6531.D_SJ2309855.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
JLC-2
Sample Collection:
17-Oct-2017 13:45

Form 1A

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	SHELL 8642
Contract No.:	2600	**Lab Sample I.D.:**	L28178-2
Matrix:	SOLID	**Sample Size:**	11.0 g (dry)
Sample Receipt Date:	26-Oct-2017	**Initial Calibration Date:**	18-Nov-2017
Extraction Date:	10-Nov-2017	**Instrument ID:**	LR GC/MS
Analysis Date:	29-Nov-2017 **Time:** 13:32:00	**GC Column ID:**	RTX5
Extract Volume (uL):	500	**Sample Data Filename:**	**PH7S6530.D**
Injection Volume (uL):	1.0	**Blank Data Filename:**	PH7S6503.D
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	PH7S6527.D
Concentration Units:	ng/g (dry weight basis)	**% Moisture:**	30.5

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
Naphthalene	91-20-3		1.22	0.123 (S)	0.07	1.006
Acenaphthylene	208-96-8	NDR	0.387	0.094 (S)	1.03	1.004
Acenaphthene	83-32-9		16.2	1.97 (S)	1.25	1.048
2-Methylfluorene	1430-97-3		5.05	1.36 (S)	1.27	0.937
C2 Phenanthrenes/Anthracenes			913	3.63 (S)		
Fluorene	86-73-7		3.02	0.200 (S)	1.07	0.843
Phenanthrene	85-01-8		96.4	3.00 (S)	0.20	1.003
Anthracene	120-12-7	ND		2.94 (S)		
C1 Phenanthrenes/Anthracenes			452	1.96 (S)		
Fluoranthene	206-44-0		11.3	2.12 (S)	0.23	1.002
Pyrene	129-00-0		36.2	2.03 (S)	0.23	1.032
Benz[a]anthracene [3]	56-55-3		17.2	1.83 (S)	0.29	1.003
Chrysene [4]	218-01-9		116	2.05 (S)	0.31	1.002
Benzo[b]fluoranthene	205-99-2		20.8	2.19 (S)	0.18	1.004
Benzo[j,k]fluoranthenes			6.25	2.20 (S)	0.22	1.002
Benzo[e]pyrene	192-97-2		46.2	3.15 (S)	0.25	0.996
Benzo[a]pyrene	50-32-8		13.6	3.05 (S)	0.21	1.004
Perylene	198-55-0		48.9	3.00 (S)	0.22	1.004
Dibenz[a,h]anthracene [5]	53-70-3		5.34	0.967 (S)	0.19	1.003
Indeno[1,2,3-cd]pyrene	193-39-5		10.2	1.36 (S)	0.21	1.002
Benzo[ghi]perylene	191-24-2		23.7	1.26 (S)	0.25	1.003
2-Methylnaphthalene	91-57-6		1.40	0.097 (S)	1.03	1.009
1-Methylnaphthalene	90-12-0		1.12	0.104 (S)	0.91	1.040
C1-Naphthalenes			2.53	0.097 (S)		
Biphenyl	92-52-4		0.892	0.193 (S)	0.34	1.005
C1-Biphenyls			2.52	0.175 (S)		
C2-Biphenyls			12.5	0.160 (S)		
C2-Naphthalenes			19.6	0.149 (S)		
1,2-Dimethylnaphthalene	573-98-8	NDR	2.77	0.149 (S)	3.39	1.081

s.19(1)

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
2,6-Dimethylnaphthalene	581-42-0	NDR	2.43	0.127 (S)	1.09	1.011
C3-Naphthalenes			143	1.02 (S)		
2,3,6-Trimethylnaphthalene	829-26-5		23.3	0.980 (S)	1.04	1.203
2,3,5-Trimethylnaphthalene	2245-38-7		17.6	1.07 (S)	1.00	1.226
C4-Naphthalenes			686	13.0 (S)		
C1-Acenaphthenes		ND		0.263 (S)		
C1-Fluorenes			79.5	1.36 (S)		
1,7-Dimethylfluorene	442-66-0		109	2.31 (S)	0.08	1.031
C2-Fluorenes			634	2.31 (S)		
C3-Fluorenes			1400	5.02 (S)		
Dibenzothiophene	132-65-0	NDR	7.45	2.84 (S)	0.80	1.002
C1-Dibenzothiophenes			64.4	4.99 (S)		
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		29.0	4.99 (S)	0.81	1.094
C2-Dibenzothiophenes			1610	3.83 (S)		
2,4-Dimethyldibenzothiophene	31317-18-7		95.3	3.83 (S)	0.57	1.162
C3-Dibenzothiophenes			3640	5.62 (S)		
C4-Dibenzothiophenes			2890	5.05 (S)		
3-Methylphenanthrene	832-71-3		83.8	2.06 (S)	0.67	1.087
2-Methylphenanthrene	2531-84-2		100	2.06 (S)	0.58	1.092
2-Methylanthracene	613-12-7	NDR	9.10	2.14 (S)	0.88	1.102
9/4-Methylphenanthrene	883-20-5/832-64-4		174	2.06 (S)	0.60	1.106
1-Methylphenanthrene	832-69-9		94.9	1.96 (S)	0.65	1.110
3,6-Dimethylphenanthrene	1576-67-6	NDR	78.4	3.67 (S)	1.17	0.969
2,6-Dimethylphenanthrene	17980-16-4		36.0	3.63 (S)	0.33	0.974
1,7-Dimethylphenanthrene	483-87-4		102	3.60 (S)	0.38	0.992
1,8-Dimethylphenanthrene	7372-87-4		43.6	3.63 (S)	0.37	1.006
C3-Phenanthrenes/Anthracenes			1360	5.44 (S)		
1,2,6-Trimethylphenanthrene	30436-55-6	NDR	72.5	5.44 (S)	0.78	1.075
Retene	483-65-8	NDR	185	7.01 (S)	0.60	1.083
C4-Phenanthrenes/Anthracenes			2260	7.01 (S)		
C1-Fluoranthenes/Pyrenes			537	4.45 (S)		
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6		162	4.45 (S)	1.05	1.083
C2-Fluoranthenes/Pyrenes			1230	2.86 (S)		
C3-Fluoranthenes/Pyrenes			879	3.10 (S)		
C4-Fluoranthenes/Pyrenes			468	2.15 (S)		
C1-Benzo[a]anthracenes/Chrysenes [4]			398	3.81 (S)		
5/6-Methylchrysene	3697-24-3/1705-85-7		40.9	3.97 (S)		1.065
1-Methylchrysene	3351-28-8		42.5	3.67 (S)		1.073
C2-Benzo[a]anthracenes/Chrysenes [4]			596	1.47 (S)		
5,9-Dimethylchrysene	139493-40-6		97.8	1.47 (S)		1.127
C3-Benzo[a]anthracenes/Chrysenes [4]			244	1.43 (S)		
C4-Benzo[a]anthracenes/Chrysenes [4]			114	4.37 (S)		
C1-Benzofluoranthenes/Benzopyrenes			218	2.25 (S)		
7-Methylbenzo[a]pyrene	63041-77-0		21.8	2.25 (S)		1.108
C2-Benzofluoranthenes/Benzopyrenes			164	19.6 (S)		
1,4,6,7-Tetramethylnaphthalene	13764-18-6	NDR	142	13.0 (S)	0.06	1.377

(1) Where applicable, custom lab flags have been used on this report; ND = not detected at RL; NDR = peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration.
(2) Reporting Limit (Code): S = sample detection limit; M = method detection limit; L = lowest calibration level equivalent; Q = minimum reporting level.
(3) May co-elute with Cyclopenta(cd)pyrene.
(4) May co-elute with Triphenylene.
(5) May co-elute with Dibenz[a,c]anthracene.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________________

For Axys Internal Use Only [XSL Template: Pest1A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_L28178-2_Form1A_PH7S6530.D_SJ2309854.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
JLC-2
Sample Collection:
17-Oct-2017 13:45

Form 2
POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**Project No.**	SHELL 8642
Matrix:	SOLID	**Lab Sample I.D.:**	L28178-2
Sample Receipt Date:	26-Oct-2017	**Sample Size:**	11.0 g (dry)
Extraction Date:	10-Nov-2017	**Initial Calibration Date:**	18-Nov-2017
Analysis Date:	29-Nov-2017 **Time:** 13:32:00	**Instrument ID:**	LR GC/MS
Extract Volume (uL):	500	**GC Column ID:**	RTX5
Injection Volume (uL):	1.0	**Sample Data Filename:**	**PH7S6530.D**
Dilution Factor:	N/A	**Blank Data Filename:**	PH7S6503.D
Concentration Units:	ng absolute	**Cal. Ver. Data Filename:**	PH7S6527.D
		% Moisture:	30.5

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

LABELED COMPOUND	LAB FLAG [1]	SPIKE CONC.	CONC. FOUND	R(%) [2]	ION ABUND. RATIO	RRT
Naphthalene d-8		2000	769	38.4	0.09	0.609
2-Methylnaphthalene d-10		2000	1120	56.1	0.17	0.755
Biphenyl d-10		2020	1340	66.2		0.868
2,6-Dimethylnaphthalene d-12		2020	1400	69.4	0.74	0.896
Acenaphthylene d-8		2000	1410	70.7	0.16	0.961
Dibenzothiophene d-8		2010	1470	72.9	0.09	0.792
Phenanthrene d-10		2010	1560	77.7	0.15	0.808
Fluoranthene d-10		2010	2000	99.6	0.17	0.971
Benzo[a]anthracene d-12		2000	1750	87.7	0.22	1.164
Chrysene d-12		2000	1660	83.2	0.26	1.169
Benzo[b]fluoranthene d-12		2020	1750	86.4	0.21	0.957
Benzo[k]fluoranthene d-12		2010	1620	80.7	0.18	0.961
Benzo[a]pyrene d-12		2010	1550	77.4	0.20	1.008
Perylene d-12		2010	1640	81.5	0.24	1.024
Dibenzo[a,h]anthracene d-14		2000	1550	77.5	0.23	1.209
Indeno[1,2,3-cd]pyrene d-12		2000	1550	77.4	0.15	1.205
Benzo[ghi]perylene d-12		2010	1490	74.3	0.19	1.236

(1) Where applicable, custom lab flags have been used on this report.
(2) R% = percent recovery.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest2.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: PAH_PAH_LO_LPAHF_L28178-2_Form2_PH7S6530.D_SJ2309854.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
LIT-1
Sample Collection:
14-Oct-2017 13:00

Form 1A

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**Project No.**	SHELL 8642
Matrix:	SOLID	**Lab Sample I.D.:**	L28178-3
Sample Receipt Date:	26-Oct-2017	**Sample Size:**	11.6 g (dry)
Extraction Date:	10-Nov-2017	**Initial Calibration Date:**	18-Nov-2017
Analysis Date:	29-Nov-2017 **Time:** 12:43:00	**Instrument ID:**	LR GC/MS
Extract Volume (uL):	500	**GC Column ID:**	RTX5
Injection Volume (uL):	1.0	**Sample Data Filename:**	**PH7S6529.D**
Dilution Factor:	N/A	**Blank Data Filename:**	PH7S6503.D
		Cal. Ver. Data Filename:	PH7S6527.D
Concentration Units:	ng/g (dry weight basis)	**% Moisture:**	36.4

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
Naphthalene	91-20-3		1.19	0.097 (S)	0.07	1.006
Acenaphthylene	208-96-8	NDR	0.179	0.062 (S)	0.30	1.003
Acenaphthene	83-32-9		0.765	0.092 (S)	1.22	1.048
2-Methylfluorene	1430-97-3		0.542	0.268 (S)	1.37	0.939
C2 Phenanthrenes/Anthracenes			79.5	0.414 (S)		
Fluorene	86-73-7		0.628	0.076 (S)	1.07	0.844
Phenanthrene	85-01-8		7.67	0.257 (S)	0.20	1.004
Anthracene	120-12-7	NDR	0.536	0.251 (S)	0.96	1.011
C1 Phenanthrenes/Anthracenes			34.0	0.734 (S)		
Fluoranthene	206-44-0		1.61	0.482 (S)	0.24	1.003
Pyrene	129-00-0		9.18	0.461 (S)	0.21	1.033
Benz[a]anthracene [3]	56-55-3	NDR	2.10	0.331 (S)	0.65	1.003
Chrysene [4]	218-01-9		29.3	0.366 (S)	0.34	1.002
Benzo[b]fluoranthene	205-99-2		6.19	0.850 (S)	0.23	1.004
Benzo[j,k]fluoranthenes		NDR	1.63	0.837 (S)	0.30	1.002
Benzo[e]pyrene	192-97-2		24.7	1.13 (S)	0.22	0.996
Benzo[a]pyrene	50-32-8		3.54	1.09 (S)	0.23	1.004
Perylene	198-55-0		19.7	0.998 (S)	0.20	1.004
Dibenz[a,h]anthracene [5]	53-70-3		3.68	0.862 (S)	0.19	1.003
Indeno[1,2,3-cd]pyrene	193-39-5		6.85	1.38 (S)	0.23	1.002
Benzo[ghi]perylene	191-24-2		24.5	1.01 (S)	0.23	1.002
2-Methylnaphthalene	91-57-6		1.32	0.074 (S)	0.96	1.009
1-Methylnaphthalene	90-12-0		0.806	0.080 (S)	0.95	1.040
C1-Naphthalenes			2.12	0.074 (S)		
Biphenyl	92-52-4		0.647	0.046 (S)	0.31	1.005
C1-Biphenyls			1.07	0.046 (S)		
C2-Biphenyls			1.84	0.045 (S)		
C2-Naphthalenes			6.13	0.157 (S)		
1,2-Dimethylnaphthalene	573-98-8		0.488	0.157 (S)	1.20	1.082

s.19(1)

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
2,6-Dimethylnaphthalene	581-42-0		1.40	0.134 (S)	0.74	1.011
C3-Naphthalenes			13.7	0.183 (S)		
2,3,6-Trimethylnaphthalene	829-26-5		3.23	0.175 (S)	0.89	1.204
2,3,5-Trimethylnaphthalene	2245-38-7		2.19	0.191 (S)	1.02	1.226
C4-Naphthalenes			21.8	0.239 (S)		
C1-Acenaphthenes		ND		0.123 (S)		
C1-Fluorenes			5.95	0.268 (S)		
1,7-Dimethylfluorene	442-66-0		4.34	0.413 (S)	0.07	1.032
C2-Fluorenes			25.4	0.413 (S)		
C3-Fluorenes			102	0.791 (S)		
Dibenzothiophene	132-65-0	NDR	1.41	0.379 (S)	0.23	1.003
C1-Dibenzothiophenes			14.6	0.616 (S)		
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		5.11	0.616 (S)	0.75	1.094
C2-Dibenzothiophenes			124	0.305 (S)		
2,4-Dimethyldibenzothiophene	31317-18-7	NDR	6.91	0.305 (S)	1.13	1.162
C3-Dibenzothiophenes			302	0.494 (S)		
C4-Dibenzothiophenes			310	1.29 (S)		
3-Methylphenanthrene	832-71-3		6.72	0.769 (S)	0.73	1.087
2-Methylphenanthrene	2531-84-2		7.47	0.769 (S)	0.52	1.092
2-Methylanthracene	613-12-7	ND		0.799 (S)		
9/4-Methylphenanthrene	883-20-5/832-64-4		12.7	0.769 (S)	0.62	1.106
1-Methylphenanthrene	832-69-9		7.08	0.734 (S)	0.66	1.110
3,6-Dimethylphenanthrene	1576-67-6	NDR	5.73	0.418 (S)	1.16	0.970
2,6-Dimethylphenanthrene	17980-16-4	NDR	4.61	0.414 (S)	0.23	0.975
1,7-Dimethylphenanthrene	483-87-4		11.3	0.410 (S)	0.37	0.993
1,8-Dimethylphenanthrene	7372-87-4		3.30	0.414 (S)	0.39	1.007
C3-Phenanthrenes/Anthracenes			132	0.988 (S)		
1,2,6-Trimethylphenanthrene	30436-55-6	NDR	5.20	0.988 (S)	1.14	1.076
Retene	483-65-8	NDR	19.3	1.62 (S)	1.23	1.083
C4-Phenanthrenes/Anthracenes			381	1.62 (S)		
C1-Fluoranthenes/Pyrenes			17.0	1.63 (S)		
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6		17.9	1.63 (S)	0.99	1.083
C2-Fluoranthenes/Pyrenes			301	0.646 (S)		
C3-Fluoranthenes/Pyrenes			332	1.09 (S)		
C4-Fluoranthenes/Pyrenes			164	1.98 (S)		
C1-Benzo[a]anthracenes/Chrysenes [4]			71.6	1.14 (S)		
5/6-Methylchrysene	3697-24-3/1705-85-7		4.72	1.18 (S)		1.065
1-Methylchrysene	3351-28-8		5.98	1.09 (S)		1.073
C2-Benzo[a]anthracenes/Chrysenes [4]			132	0.733 (S)		
5,9-Dimethylchrysene	139493-40-6		25.4	0.733 (S)		1.126
C3-Benzo[a]anthracenes/Chrysenes [4]			55.0	0.960 (S)		
C4-Benzo[a]anthracenes/Chrysenes [4]			40.4	0.776 (S)		
C1-Benzofluoranthenes/Benzopyrenes			110	0.976 (S)		
7-Methylbenzo[a]pyrene	63041-77-0		9.77	0.976 (S)		1.108
C2-Benzofluoranthenes/Benzopyrenes			72.2	1.28 (S)		
1,4,6,7-Tetramethylnaphthalene	13764-18-6	NDR	4.23	0.239 (S)	0.11	1.378

(1) Where applicable, custom lab flags have been used on this report; ND = not detected at RL; NDR = peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration.
(2) Reporting Limit (Code): S = sample detection limit; M = method detection limit; L = lowest calibration level equivalent; Q = minimum reporting level.
(3) May co-elute with Cyclopenta(cd)pyrene.
(4) May co-elute with Triphenylene.
(5) May co-elute with Dibenz[a,c]anthracene.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________ ____________

For Axys Internal Use Only [XSL Template: Pest1A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_L28178-3_Form1A_PH7S6529.D_SJ2309853.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
LIT-1
Sample Collection:
14-Oct-2017 13:00

Form 2

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**Project No.**	SHELL 8642
		Lab Sample I.D.:	L28178-3
Matrix:	SOLID	**Sample Size:**	11.6 g (dry)
Sample Receipt Date:	26-Oct-2017	**Initial Calibration Date:**	18-Nov-2017
Extraction Date:	10-Nov-2017	**Instrument ID:**	LR GC/MS
Analysis Date:	29-Nov-2017 **Time:** 12:43:00	**GC Column ID:**	RTX5
Extract Volume (uL):	500	**Sample Data Filename:**	**PH7S6529.D**
Injection Volume (uL):	1.0	**Blank Data Filename:**	PH7S6503.D
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	PH7S6527.D
Concentration Units:	ng absolute	**% Moisture:**	36.4

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

LABELED COMPOUND	LAB FLAG [1]	SPIKE CONC.	CONC. FOUND	R(%) [2]	ION ABUND. RATIO	RRT
Naphthalene d-8		2000	534	26.7	0.09	0.608
2-Methylnaphthalene d-10		2000	659	33.0	0.17	0.755
Biphenyl d-10		2020	757	37.5		0.868
2,6-Dimethylnaphthalene d-12		2020	785	38.9	0.74	0.895
Acenaphthylene d-8		2000	765	38.3	0.15	0.961
Dibenzothiophene d-8		2010	791	39.4	0.09	0.792
Phenanthrene d-10		2010	884	44.0	0.15	0.808
Fluoranthene d-10		2010	1020	51.0	0.17	0.970
Benzo[a]anthracene d-12		2000	1090	54.7	0.23	1.164
Chrysene d-12		2000	1060	53.1	0.30	1.169
Benzo[b]fluoranthene d-12		2020	1010	50.0	0.20	0.957
Benzo[k]fluoranthene d-12		2010	976	48.7	0.21	0.962
Benzo[a]pyrene d-12		2010	1010	50.3	0.19	1.008
Perylene d-12		2010	1160	57.5	0.25	1.024
Dibenzo[a,h]anthracene d-14		2000	1020	50.8	0.26	1.210
Indeno[1,2,3-cd]pyrene d-12		2000	1070	53.4	0.16	1.206
Benzo[ghi]perylene d-12		2010	1400	70.0	0.19	1.237

(1) Where applicable, custom lab flags have been used on this report.
(2) R% = percent recovery.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest2.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_L28178-3_Form2_PH7S6529.D_SJ2309853.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
Lab Blank
Sample Collection:
N/A

Form 1A

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	N/A
Contract No.:	2600	**Lab Sample I.D.:**	WG61775-101
Matrix:	SOLID	**Sample Size:**	10.0 g
Sample Receipt Date:	N/A	**Initial Calibration Date:**	18-Nov-2017
Extraction Date:	10-Nov-2017	**Instrument ID:**	LR GC/MS
Analysis Date:	28-Nov-2017 **Time:** 16:29:00	**GC Column ID:**	RTX5
Extract Volume (uL):	500	**Sample Data Filename:**	**PH7S6503.D**
Injection Volume (uL):	1.0	**Blank Data Filename:**	PH7S6503.D
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	PH7S6499.D

Concentration Units: ng/g

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
Naphthalene	91-20-3	NDR	0.367	0.098 (S)	0.14	1.006
Acenaphthylene	208-96-8	ND		0.035 (S)		
Acenaphthene	83-32-9	ND		0.093 (S)		
2-Methylfluorene	1430-97-3	ND		0.088 (S)		
C2 Phenanthrenes/Anthracenes			0.087	0.020 (S)		
Fluorene	86-73-7	ND		0.054 (S)		
Phenanthrene	85-01-8		0.182	0.046 (S)	0.20	1.004
Anthracene	120-12-7	NDR	0.077	0.045 (S)	0.23	1.012
C1 Phenanthrenes/Anthracenes		ND		0.059 (S)		
Fluoranthene	206-44-0		0.083	0.022 (S)	0.23	1.002
Pyrene	129-00-0		0.067	0.021 (S)	0.22	1.032
Benz[a]anthracene [3]	56-55-3	ND		0.020 (S)		
Chrysene [4]	218-01-9	ND		0.020 (S)		
Benzo[b]fluoranthene	205-99-2	ND		0.039 (S)		
Benzo[j,k]fluoranthenes		ND		0.039 (S)		
Benzo[e]pyrene	192-97-2	ND		0.053 (S)		
Benzo[a]pyrene	50-32-8	ND		0.051 (S)		
Perylene	198-55-0	ND		0.057 (S)		
Dibenz[a,h]anthracene [5]	53-70-3	NDR	0.034	0.030 (S)	0.68	1.003
Indeno[1,2,3-cd]pyrene	193-39-5	NDR	0.076	0.035 (S)	3.40	1.004
Benzo[ghi]perylene	191-24-2	ND		0.031 (S)		
2-Methylnaphthalene	91-57-6		0.204	0.050 (S)	0.89	1.009
1-Methylnaphthalene	90-12-0		0.107	0.054 (S)	0.90	1.040
C1-Naphthalenes			0.311	0.050 (S)		
Biphenyl	92-52-4		0.171	0.069 (S)	0.27	1.005
C1-Biphenyls			0.459	0.045 (S)		
C2-Biphenyls			0.390	0.038 (S)		
C2-Naphthalenes		ND		0.148 (S)		
1,2-Dimethylnaphthalene	573-98-8	ND		0.148 (S)		

s.19(1)

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

COMPOUND	CAS NO.	LAB FLAG [1]	CONC. FOUND	REPORTING LIMIT (RL)[2]	ION ABUND. RATIO	RRT
2,6-Dimethylnaphthalene	581-42-0	ND		0.126 (S)		
C3-Naphthalenes			0.233	0.036 (S)		
2,3,6-Trimethylnaphthalene	829-26-5		0.036	0.034 (S)	0.78	1.207
2,3,5-Trimethylnaphthalene	2245-38-7	ND		0.037 (S)		
C4-Naphthalenes		ND		0.041 (S)		
C1-Acenaphthenes		ND		0.040 (S)		
C1-Fluorenes			0.120	0.088 (S)		
1,7-Dimethylfluorene	442-66-0	ND		0.061 (S)		
C2-Fluorenes		ND		0.061 (S)		
C3-Fluorenes		ND		0.064 (S)		
Dibenzothiophene	132-65-0	ND		0.034 (S)		
C1-Dibenzothiophenes		ND		0.072 (S)		
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3	ND		0.072 (S)		
C2-Dibenzothiophenes		ND		0.032 (S)		
2,4-Dimethyldibenzothiophene	31317-18-7	ND		0.032 (S)		
C3-Dibenzothiophenes		ND		0.036 (S)		
C4-Dibenzothiophenes			0.384	0.047 (S)		
3-Methylphenanthrene	832-71-3	ND		0.062 (S)		
2-Methylphenanthrene	2531-84-2	ND		0.062 (S)		
2-Methylanthracene	613-12-7	ND		0.064 (S)		
9/4-Methylphenanthrene	883-20-5/832-64-4	ND		0.062 (S)		
1-Methylphenanthrene	832-69-9	ND		0.059 (S)		
3,6-Dimethylphenanthrene	1576-67-6	ND		0.020 (S)		
2,6-Dimethylphenanthrene	17980-16-4	ND		0.020 (S)		
1,7-Dimethylphenanthrene	483-87-4	ND		0.020 (S)		
1,8-Dimethylphenanthrene	7372-87-4	ND		0.020 (S)		
C3-Phenanthrenes/Anthracenes		ND		0.040 (S)		
1,2,6-Trimethylphenanthrene	30436-55-6	ND		0.040 (S)		
Retene	483-65-8	ND		0.061 (S)		
C4-Phenanthrenes/Anthracenes		ND		0.061 (S)		
C1-Fluoranthenes/Pyrenes		ND		0.047 (S)		
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6	ND		0.047 (S)		
C2-Fluoranthenes/Pyrenes		ND		0.033 (S)		
C3-Fluoranthenes/Pyrenes		ND		0.035 (S)		
C4-Fluoranthenes/Pyrenes		ND		0.027 (S)		
C1-Benzo[a]anthracenes/Chrysenes [4]		ND		0.023 (S)		
5/6-Methylchrysene	3697-24-3/1705-85-7	ND		0.024 (S)		
1-Methylchrysene	3351-28-8	ND		0.023 (S)		
C2-Benzo[a]anthracenes/Chrysenes [4]		ND		0.024 (S)		
5,9-Dimethylchrysene	139493-40-6	ND		0.024 (S)		
C3-Benzo[a]anthracenes/Chrysenes [4]		ND		0.026 (S)		
C4-Benzo[a]anthracenes/Chrysenes [4]		ND		0.040 (S)		
C1-Benzofluoranthenes/Benzopyrenes		ND		0.063 (S)		
7-Methylbenzo[a]pyrene	63041-77-0	ND		0.063 (S)		
C2-Benzofluoranthenes/Benzopyrenes		ND		0.041 (S)		
1,4,6,7-Tetramethylnaphthalene	13764-18-6	ND		0.041 (S)		

(1) Where applicable, custom lab flags have been used on this report; ND = not detected at RL; NDR = peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration.
(2) Reporting Limit (Code): S = sample detection limit; M = method detection limit; L = lowest calibration level equivalent; Q = minimum reporting level.
(3) May co-elute with Cyclopenta(cd)pyrene.
(4) May co-elute with Triphenylene.
(5) May co-elute with Dibenz[a,c]anthracene.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________________

For Axys Internal Use Only [XSL Template: Pest1A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_WG61775-101_Form1A_PH7S6503.D_SJ2309073.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

CLIENT SAMPLE NO.
Lab Blank
Sample Collection:
N/A

Form 2

POLYAROMATIC HYDROCARBON ANALYSIS REPORT

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

		Project No.	N/A
Contract No.:	2600	**Lab Sample I.D.:**	WG61775-101
Matrix:	SOLID	**Sample Size:**	10.0 g
Sample Receipt Date:	N/A	**Initial Calibration Date:**	18-Nov-2017
Extraction Date:	10-Nov-2017	**Instrument ID:**	LR GC/MS
Analysis Date:	28-Nov-2017 **Time:** 16:29:00	**GC Column ID:**	RTX5
Extract Volume (uL):	500	**Sample Data Filename:**	**PH7S6503.D**
Injection Volume (uL):	1.0	**Blank Data Filename:**	PH7S6503.D
Dilution Factor:	N/A	**Cal. Ver. Data Filename:**	PH7S6499.D
Concentration Units:	ng absolute		

This page is part of a total report that contains information necessary for accreditation compliance.
Results are compliant with CALA accreditation described in the total report. Sample results relate only to the sample tested.

LABELED COMPOUND	LAB FLAG [1]	SPIKE CONC.	CONC. FOUND	R(%) [2]	ION ABUND. RATIO	RRT
Naphthalene d-8		2000	831	41.5	0.09	0.607
2-Methylnaphthalene d-10		2000	947	47.4	0.17	0.755
Biphenyl d-10		2020	1030	51.0		0.868
2,6-Dimethylnaphthalene d-12		2020	1040	51.8	0.74	0.895
Acenaphthylene d-8		2000	1030	51.4	0.15	0.961
Dibenzothiophene d-8		2010	991	49.3	0.08	0.792
Phenanthrene d-10		2010	1290	64.2	0.14	0.808
Fluoranthene d-10		2010	1550	77.5	0.16	0.971
Benzo[a]anthracene d-12		2000	1760	87.9	0.24	1.164
Chrysene d-12		2000	1840	92.0	0.26	1.169
Benzo[b]fluoranthene d-12		2020	1660	82.2	0.20	0.957
Benzo[k]fluoranthene d-12		2010	1700	84.6	0.19	0.962
Benzo[a]pyrene d-12		2010	1640	81.9	0.20	1.008
Perylene d-12		2010	1630	80.9	0.25	1.024
Dibenzo[a,h]anthracene d-14		2000	1680	83.8	0.27	1.210
Indeno[1,2,3-cd]pyrene d-12		2000	1650	82.3	0.18	1.206
Benzo[ghi]perylene d-12		2010	1720	85.6	0.19	1.237

(1) Where applicable, custom lab flags have been used on this report.
(2) R% = percent recovery.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest2.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20;
Report Filename: PAH_PAH_LO_LPAHF_WG61775-101_Form2_PH7S6503.D_SJ2309073.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

Form 8A

POLYAROMATIC HYDROCARBON ONGOING PRECISION AND RECOVERY (OPR)

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**OPR Data Filename:**	**PH7S6500.D**
Matrix:	SOLID	**Lab Sample I.D.:**	WG61775-102
Extraction Date:	10-Nov-2017	**Analysis Date:**	28-Nov-2017 **Time:** 14:03:00

ALL CONCENTRATIONS REPORTED ON THIS FORM ARE CONCENTRATIONS IN EXTRACT, BASED ON 100 uL EXTRACT.

COMPOUND	CAS NO.	LAB FLAG [1]	ION ABUND. RATIO	SPIKE CONC. (ng/mL)	CONC. FOUND (ng/mL)	OPR CONC. LIMITS (ng/mL)	% RECOVERY
Naphthalene	91-20-3		0.07	19700	17500	13800 - 25600	88.6
Acenaphthylene	208-96-8		0.20	19700	19700	13800 - 27500	100
Acenaphthene	83-32-9		1.15	20100	21400	14000 - 26100	107
2-Methylfluorene	1430-97-3		1.26	20000	25400	10000 - 30000	127
Fluorene	86-73-7		0.98	19700	17700	11800 - 27500	90.0
Phenanthrene	85-01-8		0.19	20200	19700	14100 - 26200	97.8
Anthracene	120-12-7		0.19	20100	19800	14000 - 26100	98.6
Fluoranthene	206-44-0		0.20	19800	20200	13900 - 25700	102
Pyrene	129-00-0		0.21	19800	19200	13900 - 25700	97.0
Benz[a]anthracene	56-55-3		0.27	20100	19800	14100 - 26200	98.1
Chrysene	218-01-9		0.30	20100	19500	14100 - 26100	97.1
Benzo[b]fluoranthene	205-99-2		0.22	20100	20500	14100 - 26200	102
Benzo[j,k]fluoranthenes			0.22	20200	19500	14100 - 26200	96.8
Benzo[e]pyrene	192-97-2		0.22	20000	20800	14000 - 26000	104
Benzo[a]pyrene	50-32-8		0.22	20000	19700	14000 - 26000	98.4
Perylene	198-55-0		0.22	20000	20400	14000 - 26000	102
Dibenz[a,h]anthracene	53-70-3		0.17	19700	19200	13800 - 25600	97.3
Indeno[1,2,3-cd]pyrene	193-39-5		0.21	20100	20200	14100 - 26200	100
Benzo[ghi]perylene	191-24-2		0.22	19700	18400	13800 - 25600	93.4
2-Methylnaphthalene	91-57-6		0.89	20000	18700	14000 - 26000	93.9
1-Methylnaphthalene	90-12-0		0.92	20000	19000	14000 - 26000	94.9
Biphenyl	92-52-4		0.29	20100	20000	14000 - 26100	99.9
1,2-Dimethylnaphthalene	573-98-8		1.28	20000	19000	12000 - 28000	94.9
2,6-Dimethylnaphthalene	581-42-0		0.69	20000	20100	14000 - 26000	100
2,3,6-Trimethylnaphthalene	829-26-5		0.90	20000	23000	10000 - 30000	115
2,3,5-Trimethylnaphthalene	2245-38-7		0.90	20000	23300	10000 - 30000	116
1,7-Dimethylfluorene	442-66-0		0.08	20000	25200	10000 - 30000	126
Dibenzothiophene	132-65-0		0.08	20000	19700	12000 - 28000	98.4
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		0.71	20000	22800	10000 - 30000	114
2-Methylphenanthrene	2531-84-2		0.58	20000	24300	10000 - 30000	122
2-Methylanthracene	613-12-7		0.50	20000	24100	10000 - 30000	121
1-Methylphenanthrene	832-69-9		0.60	20000	24000	10000 - 30000	120
3,6-Dimethylphenanthrene	1576-67-6		0.35	20000	22000	9990 - 30000	110
1,7-Dimethylphenanthrene	483-87-4		0.34	20100	22600	10000 - 30100	113
1,2,6-Trimethylphenanthrene	30436-55-6		0.60	23300	30000	11700 - 35000	128

s.19(1)

COMPOUND	CAS NO.	LAB FLAG [1]	ION ABUND. RATIO	SPIKE CONC. (ng/mL)	CONC. FOUND (ng/mL)	OPR CONC. LIMITS (ng/mL)	% RECOVERY
Retene	483-65-8		1.63	20000	22200	9990 - 30000	111
5/6-Methylchrysene	3697-24-3/1705-85-7			20000	22600	10000 - 30000	113
1-Methylchrysene	3351-28-8			20000	23000	10000 - 30000	115
7-Methylbenzo[a]pyrene	63041-77-0			20000	22600	9980 - 30000	113
1,4,6,7-Tetramethylnaphthalene	13764-18-6		0.03	20000	25200	9980 - 39900	126

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

These pages are part of a larger report that may contain information necessary for full data evaluation. Results reported relate only to the sample tested.

For Axys Internal Use Only [XSL Template: Pest8A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: PAH_PAH_LO_LPAHF_WG61775-102_Form8A_SJ2309048.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

Form 8B

POLYAROMATIC HYDROCARBON ONGOING PRECISION AND RECOVERY (OPR)

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Contract No.:	2600	**OPR Data Filename:**	**PH7S6500.D**
Matrix:	SOLID	**Lab Sample I.D.:**	WG61775-102
Extraction Date:	10-Nov-2017	**Analysis Date:**	28-Nov-2017 **Time:** 14:03:00

ALL CONCENTRATIONS REPORTED ON THIS FORM ARE CONCENTRATIONS IN EXTRACT, BASED ON 100 uL EXTRACT.

LABELED COMPOUND	CAS NO.	LAB FLAG [1]	ION ABUND. RATIO	SPIKE CONC. (ng/mL)	CONC. FOUND (ng/mL)	OPR CONC. LIMITS (ng/mL)	% RECOVERY
Naphthalene d-8	1146-65-2		0.09	20000	8360	3000-26000	41.8
2-Methylnaphthalene d-10	7297-45-2		0.17	20000	9230	4000-26000	46.2
Biphenyl d-10	1486-01-7			20200	9590	3030-26300	47.5
2,6-Dimethylnaphthalene d-12	350820-12-1		0.74	20200	10100	4030-26200	50.2
Acenaphthylene d-8	93951-97-4		0.15	20000	8950	4000-26000	44.8
Dibenzothiophene d-8	33262-29-2		0.08	20100	9180	6030-26100	45.7
Phenanthrene d-10	1517-22-2		0.15	20100	11200	6030-26100	55.8
Fluoranthene d-10	93951-69-0		0.16	20100	12400	6020-26100	61.9
Benzo[a]anthracene d-12	1718-53-2		0.24	20000	12800	6000-26000	64.1
Chrysene d-12	1719-03-5		0.26	20000	13000	6000-26000	65.0
Benzo[b]fluoranthene d-12	93951-98-5		0.20	20200	11800	6060-26300	58.3
Benzo[k]fluoranthene d-12	93952-01-3		0.19	20100	12200	6020-26100	60.8
Benzo[a]pyrene d-12	63466-71-7		0.20	20100	11000	6020-26100	55.0
Perylene d-12	1520-96-3		0.25	20100	10400	6030-26100	51.8
Dibenzo[a,h]anthracene d-14	13250-98-1		0.28	20000	11400	6000-26000	57.1
Indeno[1,2,3-cd]pyrene d-12	203578-33-0		0.18	20000	10300	6000-26000	51.3
Benzo[ghi]perylene d-12	93951-66-7		0.19	20100	9960	6020-26100	49.7

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________________

These pages are part of a larger report that may contain information necessary for full data evaluation. Results reported relate only to the sample tested.

For Axys Internal Use Only [XSL Template: Pest8B.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: PAH_PAH_LO_LPAHF_WG61775-102_Form8B_SJ2309048.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

Form 3A
POLYAROMATIC HYDROCARBON INITIAL CALIBRATION RELATIVE RESPONSES

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**CS0 Data Filename:**	N/A
Instrument ID:	LR GC/MS	**CS1 Data Filename:**	PH7S6326.D
GC Column ID:	RTX5	**CS2 Data Filename:**	PH7S6327.D
		CS3 Data Filename:	PH7S6328.D
		CS4 Data Filename:	PH7S6330.D
		CS5 Data Filename:	PH7S6329.D
		CS6 Data Filename:	N/A

COMPOUND	LAB FLAG 1	RELATIVE RESPONSE (RR) CS0	CS1	CS2	CS3	CS4	CS5	CS6	MEAN RR	CV (%RSD)[2]
Naphthalene			1.15	1.19	1.20	1.25	1.17		1.19	3.18
Acenaphthylene			1.14	1.15	1.15	1.22	1.15		1.16	2.86
Acenaphthene			0.63	0.64	0.65	0.68	0.65		0.65	3.20
2-Methylfluorene			0.41	0.41	0.43	0.45	0.44		0.43	4.38
Fluorene			0.70	0.73	0.75	0.78	0.74		0.74	3.84
Phenanthrene			1.11	1.15	1.15	1.22	1.13		1.15	3.81
Anthracene			1.14	1.14	1.18	1.25	1.16		1.17	3.64
Fluoranthene			1.23	1.24	1.30	1.34	1.22		1.27	4.02
Pyrene			1.29	1.30	1.35	1.39	1.29		1.32	3.27
Benz[a]anthracene			1.40	1.42	1.42	1.51	1.39		1.43	3.28
Chrysene			1.24	1.27	1.29	1.36	1.26		1.28	3.62
Benzo[b]fluoranthene			1.51	1.48	1.44	1.55	1.46		1.49	2.76
Benzo[j,k]fluoranthenes			1.19	1.18	1.20	1.30	1.19		1.21	4.05
Benzo[e]pyrene			1.13	1.16	1.25	1.37	1.27		1.24	7.54
Benzo[a]pyrene			1.20	1.24	1.27	1.40	1.31		1.28	5.88
Perylene			1.31	1.39	1.43	1.58	1.48		1.44	6.91
Dibenz[a,h]anthracene			1.43	1.47	1.53	1.66	1.56		1.53	5.78
Indeno[1,2,3-cd]pyrene			1.24	1.25	1.26	1.38	1.29		1.29	4.45
Benzo[ghi]perylene			1.32	1.37	1.40	1.52	1.44		1.41	5.27
2-Methylnaphthalene			1.22	1.23	1.23	1.31	1.24		1.25	2.82
1-Methylnaphthalene			1.12	1.15	1.15	1.19	1.16		1.15	2.20
Biphenyl			1.14	1.15	1.16	1.21	1.16		1.17	2.42
C1-Biphenyls			1.14	1.15	1.16	1.21	1.16		1.17	2.42
C2-Biphenyls			1.14	1.15	1.16	1.21	1.16		1.17	2.42
1,2-Dimethylnaphthalene			1.06	1.03	1.01	1.06	1.03		1.04	1.99
2,6-Dimethylnaphthalene			1.18	1.20	1.21	1.29	1.22		1.22	3.46
C3-Naphthalenes			1.09	1.14	1.14	1.23	1.18		1.16	4.54
2,3,6-Trimethylnaphthalene			1.13	1.20	1.19	1.27	1.23		1.20	4.30
2,3,5-Trimethylnaphthalene			1.05	1.08	1.09	1.19	1.13		1.11	4.92
C4-Naphthalenes			1.11	1.16	1.17	1.25	1.22		1.18	4.75
C1-Acenaphthenes			0.63	0.64	0.65	0.68	0.65		0.65	3.20
C1-Fluorenes			0.41	0.41	0.43	0.45	0.44		0.43	4.38
1,7-Dimethylfluorene			0.44	0.46	0.47	0.50	0.48		0.47	4.80
C2-Fluorenes			0.44	0.46	0.47	0.50	0.48		0.47	4.80
C3-Fluorenes			0.44	0.46	0.47	0.50	0.48		0.47	4.80
Dibenzothiophene			1.22	1.23	1.24	1.29	1.19		1.24	2.75
2/3-Methyldibenzothiophenes			0.74	0.73	0.77	0.85	0.78		0.77	5.80
C2-Dibenzothiophenes			0.62	0.65	0.70	0.74	0.71		0.68	6.81

s.19(1)

COMPOUND	LAB FLAG 1	RELATIVE RESPONSE (RR) CS0	CS1	CS2	CS3	CS4	CS5	CS6	MEAN RR	CV (%RSD)[2]
2,4-Dimethyldibenzothiophene			0.62	0.65	0.70	0.74	0.71		0.68	6.81
C3-Dibenzothiophenes			0.62	0.65	0.70	0.74	0.71		0.68	6.81
C4-Dibenzothiophenes			0.62	0.65	0.70	0.74	0.71		0.68	6.81
3-Methylphenanthrene			0.72	0.76	0.78	0.85	0.82		0.79	6.38
2-Methylphenanthrene			0.73	0.76	0.79	0.85	0.82		0.79	5.81
2-Methylanthracene			0.67	0.73	0.75	0.82	0.81		0.76	8.12
9/4-Methylphenanthrene			0.72	0.76	0.78	0.85	0.82		0.79	6.38
1-Methylphenanthrene			0.77	0.81	0.82	0.89	0.83		0.82	5.44
3,6-Dimethylphenanthrene			0.67	0.69	0.72	0.73	0.72		0.70	3.21
2,6-Dimethylphenanthrene			0.68	0.70	0.73	0.71	0.74		0.71	3.30
1,7-Dimethylphenanthrene			0.68	0.70	0.74	0.70	0.76		0.72	4.08
1,8-Dimethylphenanthrene			0.68	0.70	0.73	0.71	0.74		0.71	3.30
C3-Phenanthrenes/Anthracenes			0.60	0.60	0.63	0.65	0.64		0.62	3.69
1,2,6-Trimethylphenanthrene			0.60	0.60	0.63	0.65	0.64		0.62	3.69
Retene			0.27	0.26	0.28	0.30	0.29		0.28	5.53
C4-Phenanthrenes/Anthracenes			0.27	0.26	0.28	0.30	0.29		0.28	5.53
3-Methylfluoranthene/Benzo[a] fluorene			0.37	0.38	0.37	0.38	0.39		0.38	2.73
C2-Fluoranthenes/Pyrenes			0.37	0.38	0.37	0.38	0.39		0.38	2.73
C3-Fluoranthenes/Pyrenes			0.37	0.38	0.37	0.38	0.39		0.38	2.73
C4-Fluoranthenes/Pyrenes			0.37	0.38	0.37	0.38	0.39		0.38	2.73
C1-Benzo[a] anthracenes/Chrysenes			0.83	0.85	0.89	0.93	0.93		0.89	5.27
5/6-Methylchrysene			0.80	0.82	0.86	0.88	0.89		0.85	4.52
1-Methylchrysene			0.86	0.87	0.92	0.98	0.97		0.92	6.06
C2-Benzo[a] anthracenes/Chrysenes			0.66	0.69	0.71	0.73	0.78		0.71	6.20
5,9-Dimethylchrysene			0.66	0.69	0.71	0.73	0.78		0.71	6.20
C3-Benzo[a] anthracenes/Chrysenes			0.66	0.69	0.71	0.73	0.78		0.71	6.20
C4-Benzo[a] anthracenes/Chrysenes			0.66	0.69	0.71	0.73	0.78		0.71	6.20
C1-Benzofluoranthenes/Benzopyrenes			0.79	0.79	0.85	0.97	0.95		0.87	9.85
7-Methylbenzo[a]pyrene			0.79	0.79	0.85	0.97	0.95		0.87	9.85
C2-Benzofluoranthenes/Benzopyrenes			0.79	0.79	0.85	0.97	0.95		0.87	9.85
1,4,6,7-Tetramethylnaphthalene			1.11	1.16	1.17	1.25	1.22		1.18	4.75

(1) Where applicable, custom lab flags have been used on this report.
(2) QC limit is 20% for native compounds with a labeled analog, 35% for those without a labeled analog.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes

Signed: ______________________

For Axys Internal Use Only [XSL Template: Form3A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_18-Nov-2017_PH7S__Form3A_GS73447.html; Workgroup: WG61775; Design ID: 526]

s.19(1) **AXYS METHOD MLA-021 Rev 12**

Form 3B
POLYAROMATIC HYDROCARBON INITIAL CALIBRATION RELATIVE RESPONSES

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date: 18-Nov-2017

Instrument ID: LR GC/MS

GC Column ID: RTX5

CS0 Data Filename: N/A
CS1 Data Filename: PH7S6326.D
CS2 Data Filename: PH7S6327.D
CS3 Data Filename: PH7S6328.D
CS4 Data Filename: PH7S6330.D
CS5 Data Filename: PH7S6329.D
CS6 Data Filename: N/A

		RELATIVE RESPONSE (RR)								
LABELED COMPOUND	LAB FLAG [1]	CS0	CS1	CS2	CS3	CS4	CS5	CS6	MEAN RR	CV (%RSD)[2]
Naphthalene d-8			1.58	1.56	1.58	1.60	1.57		1.58	0.82
2-Methylnaphthalene d-10			1.07	1.06	1.07	1.08	1.06		1.07	0.80
Biphenyl d-10			1.42	1.41	1.42	1.42	1.40		1.41	0.63
2,6-Dimethylnaphthalene d-12			0.96	0.95	0.96	0.97	0.96		0.96	0.49
Acenaphthylene d-8			1.92	1.95	1.95	1.98	1.95		1.95	1.12
Dibenzothiophene d-8			0.82	0.82	0.85	0.85	0.86		0.84	2.27
Phenanthrene d-10			0.89	0.89	0.93	0.93	0.93		0.91	2.53
Fluoranthene d-10			0.98	0.98	0.99	1.01	1.00		0.99	1.55
Benzo[a]anthracene d-12			0.82	0.83	0.81	0.82	0.83		0.82	0.81
Chrysene d-12			0.90	0.92	0.90	0.91	0.92		0.91	1.04
Benzo[b]fluoranthene d-12			0.92	0.92	0.92	0.92	0.93		0.92	0.63
Benzo[k]fluoranthene d-12			1.13	1.14	1.15	1.18	1.19		1.16	2.22
Benzo[a]pyrene d-12			0.96	0.97	0.98	0.98	1.01		0.98	1.58
Perylene d-12			0.85	0.85	0.86	0.86	0.88		0.86	1.31
Dibenzo[a,h]anthracene d-14			0.77	0.78	0.77	0.79	0.82		0.78	2.61
Indeno[1,2,3-cd]pyrene d-12			0.99	1.00	0.98	0.99	1.02		1.00	1.44
Benzo[ghi]perylene d-12			0.98	0.99	0.99	1.00	1.01		0.99	0.98

(1) Where applicable, custom lab flags have been used on this report.
(2) QC limit is 35% for labeled compounds.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________________

For Axys Internal Use Only [XSL Template: Form3B.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_18-Nov-2017_PH7S__Form3B_GS73447.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

Form 3C

POLYAROMATIC HYDROCARBON INITIAL CALIBRATION ION ABUNDANCE RATIOS

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**CS0 Data Filename:**	N/A
Instrument ID:	LR GC/MS	**CS1 Data Filename:**	PH7S6326.D
GC Column ID:	RTX5	**CS2 Data Filename:**	PH7S6327.D
		CS3 Data Filename:	PH7S6328.D
		CS4 Data Filename:	PH7S6330.D
		CS5 Data Filename:	PH7S6329.D
		CS6 Data Filename:	N/A

COMPOUND	LAB FLAG [1]	M/Z's FORMING RATIO	ION ABUNDANCE RATIO						
			CS0	CS1	CS2	CS3	CS4	CS5	CS6
Naphthalene		**128,102**		0.07	0.07	0.07	0.07	0.07	
Acenaphthylene		**152,151**		0.20	0.19	0.20	0.20	0.20	
Acenaphthene		**154,153**		1.15	1.14	1.15	1.15	1.14	
2-Methylfluorene		**180,165**		1.29	1.27	1.28	1.29	1.28	
Fluorene		**166,165**		1.02	1.02	1.01	0.99	1.00	
Phenanthrene		**178,176**		0.20	0.19	0.19	0.19	0.19	
Anthracene		**178,176**		0.18	0.19	0.18	0.19	0.19	
Fluoranthene		**202,200**		0.20	0.21	0.20	0.20	0.20	
Pyrene		**202,200**		0.20	0.21	0.21	0.21	0.21	
Benz[a]anthracene		**228,226**		0.26	0.26	0.27	0.27	0.27	
Chrysene		**228,226**		0.29	0.29	0.30	0.30	0.30	
Benzo[b]fluoranthene		**252,253**		0.24	0.23	0.22	0.22	0.22	
Benzo[j,k]fluoranthenes		**252,253**		0.21	0.22	0.22	0.22	0.22	
Benzo[e]pyrene		**252,253**		0.22	0.21	0.21	0.22	0.22	
Benzo[a]pyrene		**252,253**		0.21	0.22	0.21	0.22	0.22	
Perylene		**252,253**		0.23	0.22	0.22	0.22	0.22	
Dibenz[a,h]anthracene		**278,139**		0.17	0.17	0.17	0.18	0.18	
Indeno[1,2,3-cd]pyrene		**276,138**		0.27	0.24	0.22	0.22	0.22	
Benzo[ghi]perylene		**276,138**		0.23	0.23	0.23	0.24	0.24	
2-Methylnaphthalene		**142,141**		0.88	0.89	0.89	0.89	0.88	
1-Methylnaphthalene		**142,141**		0.91	0.92	0.92	0.92	0.92	
Biphenyl		**154,152**		0.28	0.29	0.29	0.28	0.28	
1,2-Dimethylnaphthalene		**156,141**		1.20	1.26	1.29	1.29	1.28	
2,6-Dimethylnaphthalene		**156,141**		0.69	0.69	0.69	0.69	0.69	
2,3,6-Trimethylnaphthalene		**170,155**		0.91	0.89	0.90	0.90	0.90	
2,3,5-Trimethylnaphthalene		**170,155**		0.88	0.91	0.91	0.90	0.90	
1,7-Dimethylfluorene		**194,177**		0.07	0.07	0.07	0.08	0.08	
Dibenzothiophene		**184,152**		0.09	0.09	0.08	0.08	0.08	
2/3-Methyldibenzothiophenes		**198,197**		0.69	0.71	0.71	0.71	0.71	
2,4-Dimethyldibenzothiophene		**212,197**		0.54	0.53	0.50	0.51	0.51	
3-Methylphenanthrene		**192,191**							
2-Methylphenanthrene		**192,191**		0.58	0.58	0.58	0.58	0.58	
2-Methylanthracene		**192,191**		0.51	0.49	0.50	0.50	0.50	
9/4-Methylphenanthrene		**192,191**							
1-Methylphenanthrene		**192,191**		0.64	0.57	0.60	0.60	0.60	
3,6-Dimethylphenanthrene		**206,191**		0.36	0.36	0.36	0.36	0.36	
2,6-Dimethylphenanthrene		**206,191**							
1,7-Dimethylphenanthrene		**206,191**		0.34	0.34	0.34	0.34	0.33	
1,8-Dimethylphenanthrene		**206,191**							

s.19(1)

COMPOUND	LAB FLAG [1]	M/Z's FORMING RATIO	ION ABUNDANCE RATIO						
			CS0	CS1	CS2	CS3	CS4	CS5	CS6
1,2,6-Trimethylphenanthrene		**220,205**		0.59	0.61	0.61	0.61	0.61	
Retene		**234,219**		1.66	1.69	1.64	1.67	1.65	
3-Methylfluoranthene/Benzo[a] fluorene		**216,215**		1.06	1.10	1.09	1.10	1.08	
5/6-Methylchrysene		**242**							
1-Methylchrysene		**242**							
5,9-Dimethylchrysene		**256**							
7-Methylbenzo[a]pyrene		**266**							
1,4,6,7-Tetramethylnaphthalene		**184,139**		0.03	0.03	0.03	0.03	0.03	

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Form3C.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_18-Nov-2017_PH7S__Form3C_GS73447.html; Workgroup: WG61775; Design ID: 526]

s.19(1) **AXYS METHOD MLA-021 Rev 12**

Form 3D

POLYAROMATIC HYDROCARBON INITIAL CALIBRATION ION ABUNDANCE RATIOS

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date: 18-Nov-2017

Instrument ID: LR GC/MS

GC Column ID: RTX5

CS0 Data Filename: N/A

CS1 Data Filename: PH7S6326.D

CS2 Data Filename: PH7S6327.D

CS3 Data Filename: PH7S6328.D

CS4 Data Filename: PH7S6330.D

CS5 Data Filename: PH7S6329.D

CS6 Data Filename: N/A

LABELED COMPOUND	LAB FLAG[1]	M/Z's FORMING RATIO	ION ABUNDANCE RATIO						
			CS0	CS1	CS2	CS3	CS4	CS5	CS6
Naphthalene d-8		136,134		0.09	0.09	0.09	0.09	0.09	
2-Methylnaphthalene d-10		152,151		0.17	0.17	0.17	0.17	0.17	
Biphenyl d-10		164							
2,6-Dimethylnaphthalene d-12		168,150		0.75	0.75	0.75	0.75	0.75	
Acenaphthylene d-8		160,158		0.15	0.15	0.15	0.15	0.15	
Dibenzothiophene d-8		192,160		0.09	0.09	0.09	0.09	0.09	
Phenanthrene d-10		188,184		0.14	0.14	0.14	0.14	0.14	
Fluoranthene d-10		212,208		0.16	0.17	0.17	0.17	0.17	
Benzo[a]anthracene d-12		240,236		0.24	0.24	0.24	0.24	0.24	
Chrysene d-12		240,236		0.26	0.26	0.26	0.27	0.26	
Benzo[b]fluoranthene d-12		264,260		0.21	0.21	0.21	0.21	0.20	
Benzo[k]fluoranthene d-12		264,260		0.20	0.19	0.20	0.20	0.20	
Benzo[a]pyrene d-12		264,260		0.20	0.20	0.20	0.20	0.20	
Perylene d-12		264,260		0.25	0.25	0.25	0.25	0.25	
Dibenzo[a,h]anthracene d-14		292,288		0.26	0.26	0.26	0.27	0.26	
Indeno[1,2,3-cd]pyrene d-12		288,284		0.18	0.18	0.18	0.18	0.18	
Benzo[ghi]perylene d-12		288,284		0.19	0.19	0.19	0.19	0.19	

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Form3D.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_18-Nov-2017_PH7S__Form3D_GS73447.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

Form 4A

POLYAROMATIC HYDROCARBON CALIBRATION VERIFICATION

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**VER Data Filename:**	PH7S6499.D
Instrument ID:	LR GC/MS	**Analysis Date:**	28-Nov-2017
GC Column ID:	RTX5	**Analysis Time:**	13:13:00

COMPOUND	CAS NO.	LAB FLAG [1]	m/e ION CHANNELS	ION ABUND. RATIO	SAMPLE QC LIMITS	CONC. FOUND (ng/mL)	CONC. RANGE (ng/mL)
Naphthalene	91-20-3		128,102	0.07	0.06-0.08	2100	1480-2460
Acenaphthylene	208-96-8		152,151	0.20	0.16-0.24	2110	1490-2480
Acenaphthene	83-32-9		154,153	1.15	0.92-1.38	2130	1500-2500
2-Methylfluorene	1430-97-3		180,165	1.27	1.02-1.52	2080	1500-2500
Fluorene	86-73-7		166,165	0.98	0.78-1.18	2030	1470-2460
Phenanthrene	85-01-8		178,176	0.19	0.15-0.23	2100	1490-2490
Anthracene	120-12-7		178,176	0.19	0.15-0.23	2090	1500-2490
Fluoranthene	206-44-0		202,200	0.20	0.16-0.24	2100	1500-2500
Pyrene	129-00-0		202,200	0.21	0.17-0.25	2030	1480-2460
Benz[a]anthracene	56-55-3		228,226	0.27	0.22-0.32	2030	1480-2470
Chrysene	218-01-9		228,226	0.30	0.24-0.36	2050	1500-2500
Benzo[b]fluoranthene	205-99-2		252,253	0.22	0.18-0.26	2010	1490-2490
Benzo[j,k]fluoranthenes			252,253	0.21	0.17-0.25	2020	1490-2480
Benzo[e]pyrene	192-97-2		252,253	0.22	0.18-0.26	2150	1500-2510
Benzo[a]pyrene	50-32-8		252,253	0.22	0.18-0.26	2100	1500-2500
Perylene	198-55-0		252,253	0.22	0.18-0.26	2130	1500-2510
Dibenz[a,h]anthracene	53-70-3		278,139	0.17	0.11-0.23	2120	1500-2510
Indeno[1,2,3-cd]pyrene	193-39-5		276,138	0.21	0.14-0.28	2050	1490-2480
Benzo[ghi]perylene	191-24-2		276,138	0.22	0.14-0.30	2060	1490-2480
2-Methylnaphthalene	91-57-6		142,141	0.89	0.71-1.07	2160	1540-2560
1-Methylnaphthalene	90-12-0		142,141	0.92	0.74-1.10	2080	1500-2500
Biphenyl	92-52-4		154,152	0.28	0.22-0.34	2070	1500-2500
1,2-Dimethylnaphthalene	573-98-8		156,141	1.28	1.02-1.54	2010	1500-2510
2,6-Dimethylnaphthalene	581-42-0		156,141	0.68	0.54-0.82	2110	1510-2520
2,3,6-Trimethylnaphthalene	829-26-5		170,155	0.90	0.72-1.08	2100	1500-2510
2,3,5-Trimethylnaphthalene	2245-38-7		170,155	0.90	0.72-1.08	2080	1470-2450
1,7-Dimethylfluorene	442-66-0		194,177	0.07	0.06-0.08	2120	1500-2500
Dibenzothiophene	132-65-0		184,152	0.08	0.06-0.10	2100	1510-2510
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		198,197	0.71	0.57-0.85	2190	1500-2500
2,4-Dimethyldibenzothiophene	31317-18-7		212,197	0.51	0.41-0.61	2200	1500-2500
2-Methylphenanthrene	2531-84-2		192,191	0.58	0.46-0.70	2160	1500-2500
2-Methylanthracene	613-12-7		192,191	0.50	0.40-0.60	2140	1510-2510
1-Methylphenanthrene	832-69-9		192,191	0.60	0.48-0.72	1790	1230-2040
3,6-Dimethylphenanthrene	1576-67-6		206,191	0.35	0.28-0.42	2070	1500-2510
1,7-Dimethylphenanthrene	483-87-4		206,191	0.33	0.26-0.40	1940	1500-2500
1,2,6-Trimethylphenanthrene	30436-55-6		220,205	0.60	0.48-0.72	2100	1500-2500
Retene	483-65-8		234,219	1.63	1.30-1.96	2200	1500-2500
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6		216,215	1.09	0.87-1.31	2010	1500-2500
5/6-Methylchrysene	3697-24-3/1705-85-7		242	0	N/A	2060	1500-2500
1-Methylchrysene	3351-28-8		242	0	N/A	2070	1470-2450
5,9-Dimethylchrysene	139493-40-6		256	0	N/A	2300	1670-2780
7-Methylbenzo[a]pyrene	63041-77-0		266	0	N/A	2230	1500-2500
1,4,6,7-Tetramethylnaphthalene	13764-18-6		184,139	0.03	0.02-0.04	2170	1510-2520

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest4A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_PH7S6499.D__Form4A_SJ2308833.html; Workgroup: WG61775; Design ID: 526]

AXYS METHOD MLA-021 Rev 12

Form 4B
POLYAROMATIC HYDROCARBON CALIBRATION VERIFICATION

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**VER Data Filename:**	PH7S6499.D
Instrument ID:	LR GC/MS	**Analysis Date:**	28-Nov-2017
GC Column ID:	RTX5	**Analysis Time:**	13:13:00

LABELED COMPOUND	CAS NO.	LAB FLAG [1]	m/e ION CHANNELS	ION ABUND. RATIO	SAMPLE QC LIMITS	CONC. FOUND (ng/mL)	CONC. RANGE (ng/mL)
Naphthalene d-8	1146-65-2		136,134	0.09	0.07-0.11	2000	1500-2500
2-Methylnaphthalene d-10	7297-45-2		152,151	0.17	0.14-0.20	2000	1500-2500
Biphenyl d-10	1486-01-7		164	0	N/A	2040	1520-2530
2,6-Dimethylnaphthalene d-12	350820-12-1		168,150	0.74	0.59-0.89	2050	1510-2520
Acenaphthylene d-8	93951-97-4		160,158	0.15	0.12-0.18	2010	1500-2500
Dibenzothiophene d-8	33262-29-2		192,160	0.09	0.07-0.11	1980	1510-2510
Phenanthrene d-10	1517-22-2		188,184	0.14	0.11-0.17	1990	1510-2510
Fluoranthene d-10	93951-69-0		212,208	0.16	0.13-0.19	2060	1500-2510
Benzo[a]anthracene d-12	1718-53-2		240,236	0.24	0.19-0.29	2080	1500-2500
Chrysene d-12	1719-03-5		240,236	0.26	0.21-0.31	2110	1500-2500
Benzo[b]fluoranthene d-12	93951-98-5		264,260	0.20	0.16-0.24	2020	1520-2530
Benzo[k]fluoranthene d-12	93952-01-3		264,260	0.19	0.15-0.23	2040	1500-2510
Benzo[a]pyrene d-12	63466-71-7		264,260	0.20	0.16-0.24	2000	1500-2510
Perylene d-12	1520-96-3		264,260	0.25	0.20-0.30	2010	1510-2510
Dibenzo[a,h]anthracene d-14	13250-98-1		292,288	0.26	0.17-0.35	2080	1500-2500
Indeno[1,2,3-cd]pyrene d-12	203578-33-0		288,284	0.18	0.12-0.24	2060	1500-2500
Benzo[ghi]perylene d-12	93951-66-7		288,284	0.19	0.12-0.26	2080	1500-2510

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ______________________

For Axys Internal Use Only [XSL Template: Pest4B.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_PH7S6499.D__Form4B_SJ2308833.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

Form 4A

POLYAROMATIC HYDROCARBON CALIBRATION VERIFICATION

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**VER Data Filename:**	PH7S6527.D
Instrument ID:	LR GC/MS	**Analysis Date:**	29-Nov-2017
GC Column ID:	RTX5	**Analysis Time:**	11:06:00

COMPOUND	CAS NO.	LAB FLAG [1]	m/e ION CHANNELS	ION ABUND. RATIO	SAMPLE QC LIMITS	CONC. FOUND (ng/mL)	CONC. RANGE (ng/mL)
Naphthalene	91-20-3		128,102	0.07	0.06-0.08	2110	1480-2460
Acenaphthylene	208-96-8		152,151	0.20	0.16-0.24	2100	1490-2480
Acenaphthene	83-32-9		154,153	1.14	0.91-1.37	2140	1500-2500
2-Methylfluorene	1430-97-3		180,165	1.26	1.01-1.51	2070	1500-2500
Fluorene	86-73-7		166,165	0.99	0.79-1.19	2030	1470-2460
Phenanthrene	85-01-8		178,176	0.19	0.15-0.23	2080	1490-2490
Anthracene	120-12-7		178,176	0.19	0.15-0.23	2100	1500-2490
Fluoranthene	206-44-0		202,200	0.20	0.16-0.24	2120	1500-2500
Pyrene	129-00-0		202,200	0.21	0.17-0.25	2050	1480-2460
Benz[a]anthracene	56-55-3		228,226	0.27	0.22-0.32	2030	1480-2470
Chrysene	218-01-9		228,226	0.30	0.24-0.36	2060	1500-2500
Benzo[b]fluoranthene	205-99-2		252,253	0.22	0.18-0.26	2000	1490-2490
Benzo[j,k]fluoranthenes			252,253	0.22	0.18-0.26	2050	1490-2480
Benzo[e]pyrene	192-97-2		252,253	0.22	0.18-0.26	2160	1500-2510
Benzo[a]pyrene	50-32-8		252,253	0.22	0.18-0.26	2100	1500-2500
Perylene	198-55-0		252,253	0.22	0.18-0.26	2110	1500-2510
Dibenz[a,h]anthracene	53-70-3		278,139	0.17	0.11-0.23	2110	1500-2510
Indeno[1,2,3-cd]pyrene	193-39-5		276,138	0.21	0.14-0.28	2040	1490-2480
Benzo[ghi]perylene	191-24-2		276,138	0.22	0.14-0.30	2060	1490-2480
2-Methylnaphthalene	91-57-6		142,141	0.89	0.71-1.07	2160	1540-2560
1-Methylnaphthalene	90-12-0		142,141	0.92	0.74-1.10	2080	1500-2500
Biphenyl	92-52-4		154,152	0.29	0.23-0.35	2080	1500-2500
1,2-Dimethylnaphthalene	573-98-8		156,141	1.28	1.02-1.54	2020	1500-2510
2,6-Dimethylnaphthalene	581-42-0		156,141	0.68	0.54-0.82	2110	1510-2520
2,3,6-Trimethylnaphthalene	829-26-5		170,155	0.90	0.72-1.08	2090	1500-2510
2,3,5-Trimethylnaphthalene	2245-38-7		170,155	0.90	0.72-1.08	2090	1470-2450
1,7-Dimethylfluorene	442-66-0		194,177	0.08	0.06-0.10	2140	1500-2500
Dibenzothiophene	132-65-0		184,152	0.08	0.06-0.10	2120	1510-2510
2/3-Methyldibenzothiophenes	20928-02-3/16587-52-3		198,197	0.71	0.57-0.85	2220	1500-2500
2,4-Dimethyldibenzothiophene	31317-18-7		212,197	0.50	0.40-0.60	2230	1500-2500
2-Methylphenanthrene	2531-84-2		192,191	0.58	0.46-0.70	2150	1500-2500
2-Methylanthracene	613-12-7		192,191	0.50	0.40-0.60	2140	1510-2510
1-Methylphenanthrene	832-69-9		192,191	0.60	0.48-0.72	1790	1230-2040
3,6-Dimethylphenanthrene	1576-67-6		206,191	0.35	0.28-0.42	2090	1500-2510
1,7-Dimethylphenanthrene	483-87-4		206,191	0.34	0.27-0.41	1940	1500-2500
1,2,6-Trimethylphenanthrene	30436-55-6		220,205	0.60	0.48-0.72	2140	1500-2500
Retene	483-65-8		234,219	1.62	1.30-1.94	2260	1500-2500
3-Methylfluoranthene/Benzo[a]fluorene	1706-01-0/238-84-6		216,215	1.09	0.87-1.31	2040	1500-2500
5/6-Methylchrysene	3697-24-3/1705-85-7		242	0	N/A	2070	1500-2500
1-Methylchrysene	3351-28-8		242	0	N/A	2060	1470-2450
5,9-Dimethylchrysene	139493-40-6		256	0	N/A	2300	1670-2780
7-Methylbenzo[a]pyrene	63041-77-0		266	0	N/A	2220	1500-2500
1,4,6,7-Tetramethylnaphthalene	13764-18-6		184,139	0.03	0.02-0.04	2160	1510-2520

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________________

For Axys Internal Use Only [XSL Template: Pest4A.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_PH7S6527.D__Form4A_SJ2309103.html; Workgroup: WG61775; Design ID: 526]

s.19(1)

AXYS METHOD MLA-021 Rev 12

Form 4B
POLYAROMATIC HYDROCARBON CALIBRATION VERIFICATION

SGS AXYS ANALYTICAL SERVICES
2045 MILLS RD., SIDNEY, B.C., CANADA
V8L 5X2 TEL (250) 655-5800 FAX (250) 655-5811

Initial Calibration Date:	18-Nov-2017	**VER Data Filename:**	PH7S6527.D
Instrument ID:	LR GC/MS	**Analysis Date:**	29-Nov-2017
GC Column ID:	RTX5	**Analysis Time:**	11:06:00

LABELED COMPOUND	CAS NO.	LAB FLAG [1]	m/e ION CHANNELS	ION ABUND. RATIO	SAMPLE QC LIMITS	CONC. FOUND (ng/mL)	CONC. RANGE (ng/mL)
Naphthalene d-8	1146-65-2		136,134	0.09	0.07-0.11	1970	1500-2500
2-Methylnaphthalene d-10	7297-45-2		152,151	0.17	0.14-0.20	1990	1500-2500
Biphenyl d-10	1486-01-7		164	0	N/A	2020	1520-2530
2,6-Dimethylnaphthalene d-12	350820-12-1		168,150	0.74	0.59-0.89	2040	1510-2520
Acenaphthylene d-8	93951-97-4		160,158	0.15	0.12-0.18	2010	1500-2500
Dibenzothiophene d-8	33262-29-2		192,160	0.09	0.07-0.11	1930	1510-2510
Phenanthrene d-10	1517-22-2		188,184	0.14	0.11-0.17	1940	1510-2510
Fluoranthene d-10	93951-69-0		212,208	0.16	0.13-0.19	2030	1500-2510
Benzo[a]anthracene d-12	1718-53-2		240,236	0.24	0.19-0.29	2070	1500-2500
Chrysene d-12	1719-03-5		240,236	0.26	0.21-0.31	2100	1500-2500
Benzo[b]fluoranthene d-12	93951-98-5		264,260	0.20	0.16-0.24	2020	1520-2530
Benzo[k]fluoranthene d-12	93952-01-3		264,260	0.20	0.16-0.24	2040	1500-2510
Benzo[a]pyrene d-12	63466-71-7		264,260	0.20	0.16-0.24	2010	1500-2510
Perylene d-12	1520-96-3		264,260	0.25	0.20-0.30	2020	1510-2510
Dibenzo[a,h]anthracene d-14	13250-98-1		292,288	0.27	0.18-0.36	2080	1500-2500
Indeno[1,2,3-cd]pyrene d-12	203578-33-0		288,284	0.18	0.12-0.24	2070	1500-2500
Benzo[ghi]perylene d-12	93951-66-7		288,284	0.19	0.12-0.26	2060	1500-2510

(1) Where applicable, custom lab flags have been used on this report.

These data are validated and reported as accurate and in accord with SGS AXYS Analytical Services Ltd. ISO17025 compliant quality assurance processes.

Signed: ____________ ____________

For Axys Internal Use Only [XSL Template: Pest4B.xsl; Created: 07-Dec-2017 15:40:40; Application: XMLTransformer-1.16.20; Report Filename: GENERIC-SPECS_PAH_LO_PH7S6527.D__Form4B_SJ2309103.html; Workgroup: WG61775; Design ID: 526]

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
BFR	BTBPE	SGS AXYS MLA-033	MLA-033			Y											Y								Y											
	DBDPE	SGS AXYS MLA-033	MLA-033			Y											Y								Y											
	HBB	SGS AXYS MLA-033	MLA-033			Y											Y								Y											
	PBEB	SGS AXYS MLA-033	MLA-033			Y											Y								Y											
BPA and MPE	4,4'-dihydroxy-2,2-diphenylpropane (Bisphenol A) (BPA)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-(3-carboxypropyl) phthalate (MCPP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-2-ethylhexyl phthalate (MEHP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-benzyl phthalate (MBzP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-butyl phthalate (MBP) (n + iso)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-cyclohexyl phthalate (MCHP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-ethyl phthalate (MEP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-iso-nonyl phthalate (MiNP)	SGS AXYS MLA-059	MLA-059																					Y												
	Mono-methyl phthalate (MMP)	SGS AXYS MLA-059	MLA-059																					Y												
HBCDD	alpha-hexabromocyclododecane (a-HBCDD)	SGS AXYS MLA-070	MLA-070		Y																															
	beta-hexabromocyclododecane (b-HBCDD)	SGS AXYS MLA-070	MLA-070		Y																															
	gamma-hexabromocyclododecane (g-HBCDD)	SGS AXYS MLA-070	MLA-070		Y																															
OC Pesticides	2,4'-DDD	EPA 625	MLA-007																								Y									
		EPA 8270	MLA-007					Y					Y																							
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y								Y		Y									
	2,4'-DDE	EPA 625	MLA-007																								Y									
		EPA 8270	MLA-007					Y					Y																							
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y								Y		Y									
	2,4'-DDT	EPA 625	MLA-007																								Y									
		EPA 8270	MLA-007					Y					Y																							
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y								Y		Y									
	4,4'-DDD	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	4,4'-DDE	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	4,4'-DDT	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Aldrin	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp CALA	Serum CALA	Solids CALA	Solids California DPH	Solids Florida DOH	Solids Minnesota DOH	Solids New Jersey DEP	Solids New York DOH	Solids Virginia DGS	Solids Washington DE	Solids Maine DOH	Solids ANAB	Solids DoD	Tissue CALA	Tissue Florida DOH	Tissue Minnesota DOH	Tissue New Jersey DEP	Tissue Virginia DGS	Tissue ANAB	Tissue DoD	Urine CALA	Water CALA	Water, Non-Potable California DPH	Water, Non-Potable Florida DOH	Water, Non-Potable Minnesota DOH	Water, Non-Potable New Jersey DEP	Water, Non-Potable New York DOH	Water, Non-Potable Virginia DGS	Water, Non-Potable Washington DE *	Water, Non-Potable Maine DOH	Water, Non-Potable ANAB	Water, Non-Potable Pennsylvania DEP	Water, Non-Potable DoD
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Alpha-HCH	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Beta-HCH	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Chlordane, technical	EPA 625	MLA-007																							Y							Y			
		EPA 8270	MLA-007				Y	Y			Y	Y		Y	Y												Y			Y	Y		Y	Y		
		SGS AXYS MLA-007	MLA-007					Y							Y												Y							Y		
	cis-Chlordane (alpha-Chlordane)	EPA 8270	MLA-007					Y			Y		Y	Y	Y												Y			Y			Y	Y		
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	cis-Nonachlor	EPA 8270	MLA-007					Y					Y														Y									
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y								Y		Y									
	Delta-HCH	EPA 608	MLA-007																								Y			Y	Y		Y	Y		
		EPA 8081	MLA-007					Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Dieldrin	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Endosulphan I	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Endosulphan II	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Endosulphan sulphate	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Endrin	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Endrin aldehyde	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y										Y		Y							Y		
	Endrin ketone	EPA 8081	MLA-007					Y			Y		Y		Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y				
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Gamma-HCH (Lindane)	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Heptachlor	EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Heptachlor epoxide	EPA 608	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Hexachlorobenzene	EPA 1625	MLA-007																							Y	Y			Y				Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Methoxychlor	EPA 608	MLA-007																								Y			Y	Y			Y		
		EPA 8081	MLA-007				Y	Y			Y	Y	Y	Y	Y																					
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Mirex	EPA 8270	MLA-007					Y			Y		Y		Y												Y			Y	Y		Y	Y		
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	Oxychlordane	EPA 8270	MLA-007					Y					Y														Y									
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y								Y		Y									
	Toxaphene	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	trans-Chlordane (gamma-Chlordane)	EPA 8270	MLA-007					Y			Y		Y	Y	Y												Y			Y			Y	Y		
		EPA 1699	MLA-028					Y							Y												Y							Y		

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
				CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y							Y		Y								Y		Y							Y		
	trans-Nonachlor	EPA 8270	MLA-007					Y					Y														Y									
		EPA 1699	MLA-028					Y							Y												Y							Y		
		SGS AXYS MLA-028	MLA-028		Y	Y		Y					Y		Y		Y								Y		Y					Y		Y		
		SGS AXYS MLA-007	MLA-007		Y	Y		Y									Y										Y									
PAH	1,2,6-Trimethylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1,2-Dimethylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1,4,6,7-Tetramethylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1,7-Dimethylfluorene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1,7-Dimethylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1,8-Dimethylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1-Methylchrysene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1-Methylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	1-Methylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2,3,5-Trimethylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2,3,6-Trimethylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2,4-Dimethyldibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2,6-Dimethylnaphthalene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2,6-Dimethylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2/3-Methyldibenzothiophenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2-Methylanthracene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2-Methylfluorene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	2-methylnaphthalene	EPA 1625	MLA-021																															Y		
		EPA 8270	MLA-021					Y			Y				Y												Y									
		SGS AXYS MLA-021	MLA-021			Y		Y							Y										Y									Y		
	2-Methylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	3,6-Dimethylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	3-Methylfluoranthene/ Benzo(a)fluorene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	3-Methylphenanthrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	5,9-Dimethylchrysene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	5/6-Methylchrysenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	7-Methylbenzo(a)pyrene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	9/4-Methylphenanthrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	Acenaphthene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Acenaphthylene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Anthracene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Benz[a]anthracene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Benzo[a]pyrene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Benzo[b]fluoranthene	EPA 1625	MLA-021																							Y	Y			Y	Y		Y	Y		

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp CALA	Serum CALA	Solids CALA	Solids California DPH	Solids Florida DOH	Solids Minnesota DOH	Solids New Jersey DEP	Solids New York DOH	Solids Virginia DGS	Solids Washington DE	Solids Maine DOH	Solids ANAB	Solids DoD	Tissue CALA	Tissue Florida DOH	Tissue Minnesota DOH	Tissue New Jersey DEP	Tissue Virginia DGS	Tissue ANAB	Tissue DoD	Urine CALA	Water CALA	Water, Non-Potable California DPH	Water, Non-Potable Florida DOH	Water, Non-Potable Minnesota DOH	Water, Non-Potable New Jersey DEP	Water, Non-Potable New York DOH	Water, Non-Potable Virginia DGS	Water, Non-Potable Washington DE *	Water, Non-Potable Maine DOH	Water, Non-Potable ANAB	Water, Non-Potable Pennsylvania DEP	Water, Non-Potable DoD
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Benzo[e]pyrene	SGS AXYS MLA-021	MLA-021			Y											Y								Y											
	Benzo[ghi]perylene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Benzo[j/k]fluoranthenes	SGS AXYS MLA-021	MLA-021																						Y											
	Benzo[k]fluoranthene	EPA 1625	MLA-021																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-021					Y			Y			Y	Y																					
		SGS AXYS MLA-021	MLA-021					Y							Y		Y								Y		Y							Y		
	Biphenyl	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Acenaphthenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Benz(a)anthracenes/chrysenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Benzofluoranthenes/ Benzopyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Biphenyls	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Dibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Fluoranthenes/Pyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Fluorenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Naphthalenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C1-Phenanthrenes/Anthracenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Benz(a)anthracenes/Chrysenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Benzofluoranthenes/ Benzopyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Biphenyls	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Dibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Fluoranthenes/Pyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Fluorenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Naphthalenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C2-Phenanthrenes/Anthracenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Benz(a)anthracenes/Chrysenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Dibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Fluoranthenes/Pyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Fluorenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Naphthalenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C3-Phenanthrenes/Anthracenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C4-Benz(a)anthracenes/Chrysenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C4-Dibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C4-Fluoranthenes/Pyrenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C4-Naphthalenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	C4-Phenanthrenes/Anthracenes	SGS AXYS MLA-021	MLA-021			Y																			Y											
	Chrysene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Dibenz[ah]anthracene	SGS AXYS MLA-021	MLA-021			Y											Y								Y											
	Dibenzo[ah]anthracene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021					Y							Y												Y							Y		
	Dibenzothiophene	SGS AXYS MLA-021	MLA-021			Y																			Y											
	Fluoranthene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp CALA	Serum CALA	Solids CALA	Solids California DPH	Solids Florida DOH	Solids Minnesota DOH	Solids New Jersey DEP	Solids New York DOH	Solids Virginia DGS	Solids Washington DE	Solids Maine DOH	Solids ANAB	Solids DoD	Tissue CALA	Tissue Florida DOH	Tissue Minnesota DOH	Tissue New Jersey DEP	Tissue Virginia DGS	Tissue ANAB	Tissue DoD	Urine CALA	Water CALA	Water, Non-Potable California DPH	Water, Non-Potable Florida DOH	Water, Non-Potable Minnesota DOH	Water, Non-Potable New Jersey DEP	Water, Non-Potable New York DOH	Water, Non-Potable Virginia DGS	Water, Non-Potable Washington DE *	Water, Non-Potable Maine DOH	Water, Non-Potable ANAB	Water, Non-Potable Pennsylvania DEP	Water, Non-Potable DoD
	Fluorene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Indeno[1,2,3-cd]pyrene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Naphthalene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Perylene	SGS AXYS MLA-021	MLA-021			Y											Y								Y											
	Phenanthrene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Pyrene	EPA 1625	MLA-021																							Y	Y			Y	Y			Y		
		EPA 8270	MLA-021				Y	Y			Y	Y		Y	Y																					
		SGS AXYS MLA-021	MLA-021			Y		Y							Y		Y								Y		Y							Y		
	Retene	SGS AXYS MLA-021	MLA-021			Y											Y								Y											
PBDPE	BDE 10 2,6-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 100 2,2',4,4',6-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 105 2,3,3',4,4'-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 11 3,3'-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 116 2,3,4,5,6-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 119 2,3',4,4',6-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 12 3,4-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 126 3,3',4,4',5-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 13 3,4'-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 140 2,2',3,4,4',6'-hexabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 15 4,4'-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 153 2,2',4,4',5,5'-hexabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 154 2,2',4,4',5',6-hexabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 155 2,2',4,4',6,6'-hexabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 166 2,3,4,4',5,6-hexabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 17 2,2',4-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 181 2,2',3,4,4',5,6-heptabromodiphenylether	EPA 1614	MLA-033										Y																			Y				

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 190 2,3,3',4,4',5,6-heptabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 206 2,2',3,3',4,4',5,5',6-nonabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 207 2,2',3,3',4,4',5,6,6'-nonabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 208 2,2',3,3',4,5,5',6,6'-nonabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 209 Decabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 25 2,3',4-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 28 2,4,4'-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 30 2,4,6-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 35 3,3',4-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 37 3,4,4'-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 47 2,2',4,4'-tetrabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 49 2,2',4,5'-tetrabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 66 2,3',4,4'-tetrabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 7 2,4-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 75 2,4,4',6-tetrabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 77 3,3',4,4'-tetrabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 8 2,4'-dibromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 85 2,2',3,4,4'-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE 99 2,2',4,4',5-pentabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE-183 2,2',3,4,4',5',6-heptabromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
	BDE-33 2',3,4-tribromodiphenylether	EPA 1614	MLA-033										Y																			Y				
		SGS AXYS MLA-033	MLA-033		Y	Y											Y								Y											
PCB Aroclors	PCB Aroclor 1016	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y			Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1016/1242	EPA 8270	MLA-007										Y																							
	PCB Aroclor 1221	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		

Accreditation Scope
SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y		Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1232	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y		Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1242	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y			Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1248	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y		Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1254	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y		Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1260	EPA 1668	MLA-010					Y						Y	Y												Y						Y	Y		
		EPA 625	MLA-007																							Y	Y			Y	Y		Y	Y		
		EPA 8270	MLA-007				Y	Y			Y	Y	Y		Y																					
		SGS AXYS MLA-010	MLA-010					Y							Y												Y							Y		
		SGS AXYS MLA-007	MLA-007			Y		Y							Y		Y								Y		Y							Y		
	PCB Aroclor 1268	SGS AXYS MLA-007	MLA-007			Y											Y								Y											
PCB congeners	PCB 1 2-Chlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 10 2,6-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y			Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 100 2,2',4,4',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 101 2,2',4,5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 101/90/89	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 102 2,2',4,5,6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 103 2,2',4,5',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 104 2,2',4,6,6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp: CALA	Serum: CALA	Solids: CALA	Solids: California DPH	Solids: Florida DOH	Solids: Minnesota DOH	Solids: New Jersey DEP	Solids: New York DOH	Solids: Virginia DGS	Solids: Washington DE	Solids: Maine DOH	Solids: ANAB	Solids: DoD	Tissue: CALA	Tissue: Florida DOH	Tissue: Minnesota DOH	Tissue: New Jersey DEP	Tissue: Virginia DGS	Tissue: ANAB	Tissue: DoD	Urine: CALA	Water: CALA	Water, Non-Potable: California DPH	Water, Non-Potable: Florida DOH	Water, Non-Potable: Minnesota DOH	Water, Non-Potable: New Jersey DEP	Water, Non-Potable: New York DOH	Water, Non-Potable: Virginia DGS	Water, Non-Potable: Washington DE *	Water, Non-Potable: Maine DOH	Water, Non-Potable: ANAB	Water, Non-Potable: Pennsylvania DEP	Water, Non-Potable: DoD
	PCB 105 2,3,3',4,4'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 105/127	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 106 2,3,3',4,5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 107 2,3,3',4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 107/109	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 108 2,3,3',4,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 109 2,3,3',4,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 11 3,3'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 110 2,3,3',4',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 111 2,3,3',5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 111/117	EPA 8270	MLA-007										Y																							
	PCB 112 2,3,3',5,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 113 2,3,3',5',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 114 2,3,4,4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 115 2,3,4,4',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 116 2,3,4,5,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 117 2,3,4',5,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 118 2,3',4,4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 118/106	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 119 2,3',4,4',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 12 3,4-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 12/13	EPA 8270	MLA-007										Y																							

www.axysanalytical.com

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 120 2,3',4,5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 121 2,3',4,5',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 122 2,3,3',4',5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 123 2,3',4,4',5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 124 2,3',4',5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 125 2,3',4',5',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 126 3,3',4,4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 127 3,3',4,5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 128 2,2',3,3',4,4'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 129 2,2',3,3',4,5-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 13 3,4'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 130 2,2',3,3',4,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 131 2,2',3,3',4,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 131/142	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 132 2,2',3,3',4,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 132/168	EPA 8270	MLA-007										Y																							
	PCB 133 2,2',3,3',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 134 2,2',3,3',5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 134/143	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											

www.axysanalytical.com

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 135 2,2',3,3',5,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 136 2,2',3,3',6,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 137 2,2',3,4,4',5-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 138 2,2',3,4,4',5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 138/163/164	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 139 2,2',3,4,4',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 14 3,5-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 140 2,2',3,4,4',6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 141 2,2',3,4,5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 142 2,2',3,4,5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 143 2,2',3,4,5,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 144 2,2',3,4,5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 144/135	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 145 2,2',3,4,6,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 146 2,2',3,4',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 147 2,2',3,4',5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 148 2,2',3,4',5,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 149 2,2',3,4',5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp CALA	Serum CALA	Solids CALA	Solids California DPH	Solids Florida DOH	Solids Minnesota DOH	Solids New Jersey DEP	Solids New York DOH	Solids Virginia DGS	Solids Washington DE	Solids Maine DOH	Solids ANAB	Solids DoD	Tissue CALA	Tissue Florida DOH	Tissue Minnesota DOH	Tissue New Jersey DEP	Tissue Virginia DGS	Tissue ANAB	Tissue DoD	Urine CALA	Water CALA	Water, Non-Potable California DPH	Water, Non-Potable Florida DOH	Water, Non-Potable Minnesota DOH	Water, Non-Potable New Jersey DEP	Water, Non-Potable New York DOH	Water, Non-Potable Virginia DGS	Water, Non-Potable Washington DE *	Water, Non-Potable Maine DOH	Water, Non-Potable ANAB	Water, Non-Potable Pennsylvania DEP	Water, Non-Potable DoD
	PCB 149/139	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 15 4,4'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 150 2,2',3,4',6,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 151 2,2',3,5,5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 152 2,2',3,5,6,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 153 2,2',4,4',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 154 2,2',4,4',5,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 155 2,2',4,4',6,6'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 156 2,3,3',4,4',5-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 157 2,3,3',4,4',5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 158 2,3,3',4,4',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 158/160	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 159 2,3,3',4,5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 16 2,2',3-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 16/32	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 160 2,3,3',4,5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 161 2,3,3',4,5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 162 2,3,3',4',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 163 2,3,3',4',5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 164 2,3,3',4',5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 165 2,3,3',5,5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 166 2,3,4,4',5,6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 167 2,3',4,4',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 168 2,3',4,4',5',6-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 169 3,3',4,4',5,5'-Hexachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 17 2,2',4-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 170 2,2',3,3',4,4',5-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 170/190	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 171 2,2',3,3',4,4',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 172 2,2',3,3',4,5,5'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 172/192	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 173 2,2',3,3',4,5,6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 174 2,2',3,3',4,5,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 174/181	EPA 8270	MLA-007										Y																							

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 175 2,2',3,3',4,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 176 2,2',3,3',4,6,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 177 2,2',3,3',4,5',6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 178 2,2',3,3',5,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 179 2,2',3,3',5,6,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 18 2,2',5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 180 2,2',3,4,4',5,5'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 181 2,2',3,4,4',5,6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 182 2,2',3,4,4',5,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 183 2,2',3,4,4',5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 184 2,2',3,4,4',6,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 185 2,2',3,4,5,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 186 2,2',3,4,5,6,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 187 2,2',3,4',5,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 187/182	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 188 2,2',3,4',5,6,6'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 189 2,3,3',4,4',5,5'-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 19 2,2',6-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 190 2,3,3',4,4',5,6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 191 2,3,3',4,4',5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 192 2,3,3',4,5,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 193 2,3,3',4',5,5',6-Heptachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 194 2,2',3,3',4,4',5,5'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 195 2,2',3,3',4,4',5,6-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 196 2,2',3,3',4,4',5,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 196/203	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 197 2,2',3,3',4,4',6,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 198 2,2',3,3',4,5,5',6-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 199 2,2',3,3',4,5,5',6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 2 3-Chlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 20 2,3,3'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 200 2,2',3,3',4,5,6,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 201 2,2',3,3',4,5',6,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 202 2,2',3,3',5,5',6,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 203 2,2',3,4,4',5,5',6-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 204 2,2',3,4,4',5,6,6'-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 205 2,3,3',4,4',5,5',6-Octachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 206 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 207 2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 208 2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 209 Decachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 21 2,3,4-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 22 2,3,4'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 23 2,3,5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 23/34	EPA 8270	MLA-007										Y																							

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 24 2,3,6-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 24/27	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 25 2,3',4-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 26 2,3',5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 27 2,3',6-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 28 2,4,4'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 29 2,4,5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y		Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 3 4-Chlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 30 2,4,6-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 31 2,4',5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 32 2,4',6-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 33 2,3',4'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 33/20/21	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 34 2,3',5'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 35 3,3',4-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 36 3,3',5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 37 3,4,4'-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 38 3,4,5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 39 3,4',5-Trichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 4 2,2'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 4/10	EPA 8270	MLA-007										Y																							
	PCB 40 2,2',3,3'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 41 2,2',3,4-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 41/71/64/68	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 42 2,2',3,4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 42/59	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 43 2,2',3,5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 44 2,2',3,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 45 2,2',3,6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 46 2,2',3,6'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 47 2,2',4,4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 47/48/75	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 48 2,2',4,5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 49 2,2',4,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 49/43	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 5 2,3-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 50 2,2',4,6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 51 2,2',4,6'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 52 2,2',5,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 52/73	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 53 2,2',5,6'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 54 2,2',6,6'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 55 2,3,3',4-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 56 2,3,3',4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 56/60	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 57 2,3,3',5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 58 2,3,3',5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 59 2,3,3',6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 6 2,3'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 60 2,3,4,4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 61 2,3,4,5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 62 2,3,4,6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 62/65	EPA 8270	MLA-007										Y																							
	PCB 63 2,3,4',5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 64 2,3,4',6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 65 2,3,5,6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 66 2,3',4,4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 66/80	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 67 2,3',4,5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 68 2,3',4,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 69 2,3',4,6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 7 2,4-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 7/9	EPA 8270	MLA-007										Y																							
	PCB 70 2,3',4',5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 70/76	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 71 2,3',4',6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 72 2,3',5,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 73 2,3',5',6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 74 2,4,4',5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB 74/61	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 75 2,4,4',6-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 76 2,3',4',5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 77 3,3',4,4'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 78 3,3',4,5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 79 3,3',4,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 8 2,4'-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 8/5	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 80 3,3',5,5'-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 81 3,4,4',5-Tetrachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 82 2,2',3,3',4-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
				CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 83 2,2',3,3',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 83/108	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 84 2,2',3,3',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 85 2,2',3,4,4'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 85/120	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 86 2,2',3,4,5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 87 2,2',3,4,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 87/115/116	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 88 2,2',3,4,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 88/121	EPA 8270	MLA-007										Y																							
	PCB 89 2,2',3,4,6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 9 2,5-Dichlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y			Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 90 2,2',3,4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 91 2,2',3,4',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 92 2,2',3,5,5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 93 2,2',3,5,6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 94 2,2',3,5,6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 95 2,2',3,5',6-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 95/93	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	PCB 96 2,2',3,6,6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 97 2,2',3,4',5'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 97/86	EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
				CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	PCB 98 2,2',3,4',6'-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
	PCB 98/102	EPA 8270	MLA-007										Y																							
	PCB 99 2,2',4,4',5-Pentachlorobiphenyl	EPA 1668	MLA-010					Y		Y	Y	Y	Y	Y	Y	Y						Y	Y				Y		Y	Y	Y	Y		Y	Y	Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y		Y							Y	Y	Y					Y	Y		Y		Y							Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
		SGS AXYS MLA-901	MLA-901		Y																															
	PCB congeners, total	EPA 1668	MLA-010								Y																			Y						
	Sum - Dichlorobiphenyls (BZ-12-+ BZ-13)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Heptachlorobiphenyls (BZ-171 + BZ-173)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Heptachlorobiphenyls (BZ-180 + BZ-193)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Heptachlorobiphenyls (BZ-183 + BZ-185)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-128 + BZ-166)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-129 + BZ-138 + BZ-160 + BZ-163)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-134 + BZ-143)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-135 + BZ-151 + BZ-154)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-139 + BZ-140)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-147 + BZ-149)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-153 + BZ-168)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Hexachlorobiphenyls (BZ-156 + BZ-157)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-107 + BZ-124)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-108 + BZ-124)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-110 + BZ-115)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-83 + BZ-99)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-85 + BZ-116 + BZ-117)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-86 + BZ-87 + BZ 97 + BZ-109 + BZ-119 + BZ-125)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-86 + BZ-87 + BZ-97 + BZ-108 + BZ-119 +BZ-125)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-88 + BZ-91)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-90 + BZ-101 + BZ-113)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	Pulp CALA	Serum CALA	Solids CALA	Solids California DPH	Solids Florida DOH	Solids Minnesota DOH	Solids New Jersey DEP	Solids New York DOH	Solids Virginia DGS	Solids Washington DE	Solids Maine DOH	Solids ANAB	Solids DoD	Tissue CALA	Tissue Florida DOH	Tissue Minnesota DOH	Tissue New Jersey DEP	Tissue Virginia DGS	Tissue ANAB	Tissue DoD	Urine CALA	Water CALA	Water, Non-Potable California DPH	Water, Non-Potable Florida DOH	Water, Non-Potable Minnesota DOH	Water, Non-Potable New Jersey DEP	Water, Non-Potable New York DOH	Water, Non-Potable Virginia DGS	Water, Non-Potable Washington DE *	Water, Non-Potable Maine DOH	Water, Non-Potable ANAB	Water, Non-Potable Pennsylvania DEP	Water, Non-Potable DoD
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Pentachlorobiphenyls (BZ-93 + BZ-95 + BZ-98 + BZ-100 + BZ-102)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-40 + BZ-41 + BZ-71)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-44 + BZ-47 + BZ-65)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-45 + BZ-51)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-49 + BZ-69)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-50 + BZ-53)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-59 + BZ-62 + BZ-75)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Tetrachlorobiphenyls (BZ-61 + BZ-70 + BZ-74 + BZ-76)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Trichlorobiphenyls (BZ-18 + BZ-30)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Trichlorobiphenyls (BZ-20 + BZ-28)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Trichlorobiphenyls (BZ-21 + BZ-33)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Sum - Trichlorobiphenyls (BZ-26 + BZ-29)	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Total Dichlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	Total Heptachlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	Total Hexachlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	Total Monochlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
	Total Nonachlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	Total Octachlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007										Y																							
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007			Y											Y								Y											
	Total PCBs	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-010	MLA-010												Y	Y						Y	Y											Y		Y
	Total Pentachlorobiphenyls	EPA 1668	MLA-010												Y	Y						Y	Y											Y		Y

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp: CALA	Serum: CALA	Solids: CALA	Solids: California DPH	Solids: Florida DOH	Solids: Minnesota DOH	Solids: New Jersey DEP	Solids: New York DOH	Solids: Virginia DGS	Solids: Washington DE	Solids: Maine DOH	Solids: ANAB	Solids: DoD	Tissue: CALA	Tissue: Florida DOH	Tissue: Minnesota DOH	Tissue: New Jersey DEP	Tissue: Virginia DGS	Tissue: ANAB	Tissue: DoD	Urine: CALA	Water: CALA	Water, Non-Potable: California DPH	Water, Non-Potable: Florida DOH	Water, Non-Potable: Minnesota DOH	Water, Non-Potable: New Jersey DEP	Water, Non-Potable: New York DOH	Water, Non-Potable: Virginia DGS	Water, Non-Potable: Washington DE *	Water, Non-Potable: Maine DOH	Water, Non-Potable: ANAB	Water, Non-Potable: Pennsylvania DEP	Water, Non-Potable: DoD
		EPA 8270	MLA-007									Y																						
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007		Y											Y								Y											
	Total Polychlorinated biphenyls	SGS AXYS MLA-007	MLA-007		Y											Y								Y											
	Total Tetrachlorobiphenyls	EPA 1668	MLA-010											Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007									Y																						
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007		Y											Y								Y											
	Total Trichlorobiphenyls	EPA 1668	MLA-010											Y	Y						Y	Y											Y		Y
		EPA 8270	MLA-007									Y																						
		SGS AXYS MLA-010	MLA-010		Y	Y									Y	Y	Y					Y	Y		Y									Y		Y
		SGS AXYS MLA-007	MLA-007		Y											Y								Y											
PCDDF	1,2,3,4,6,7,8-HpCDD	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,4,6,7,8-HpCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,4,7,8,9-HpCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,4,7,8-HxCDD	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,4,7,8-HxCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,6,7,8-HxCDD	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,6,7,8-HxCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,7,8,9-HxCDD	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,7,8,9-HxCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,7,8-PeCDD	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	1,2,3,7,8-PeCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	2,3,4,6,7,8-HxCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	2,3,4,7,8-PeCDF	EPA 1613	MLA-017									Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017			Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y

www.axysanalytical.com

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	2,3,7,8-TCDD	EPA 1613	MLA-017										Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017				Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	2,3,7,8-TCDF	EPA 1613	MLA-017										Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017				Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	OCDD	EPA 1613	MLA-017										Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017				Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	OCDF	EPA 1613	MLA-017										Y		Y	Y						Y	Y			Y	Y		Y	Y	Y	Y	Y	Y		Y
		EPA 8290	MLA-017				Y	Y		Y	Y	Y		Y	Y	Y		Y		Y	Y	Y	Y				Y			Y	Y			Y		Y
		SGS AXYS MLA-017	MLA-017	Y	Y	Y		Y							Y	Y	Y	Y				Y	Y		Y		Y							Y		Y
	Total HpCDD	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total HpCDF	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total HxCDD	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total HxCDF	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total PCDD	EPA 1613	MLA-017												Y	Y						Y	Y											Y		Y
		EPA 8290	MLA-017												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-017	MLA-017												Y	Y						Y	Y											Y		Y
	Total PCDD+PCDF	EPA 1613	MLA-017												Y	Y						Y	Y											Y		Y
		EPA 8290	MLA-017												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-017	MLA-017												Y	Y						Y	Y											Y		Y
	Total PCDF	EPA 1613	MLA-017												Y	Y						Y	Y											Y		Y
		EPA 8290	MLA-017												Y	Y						Y	Y											Y		Y
		SGS AXYS MLA-017	MLA-017												Y	Y						Y	Y											Y		Y
	Total PeCDD	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total PeCDF	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total TCDD	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
	Total TCDF	EPA 1613	MLA-017												Y	Y						Y	Y			Y	Y						Y	Y		Y
		EPA 8290	MLA-017					Y		Y		Y		Y	Y	Y		Y		Y	Y	Y	Y				Y				Y			Y		Y
		SGS AXYS MLA-017	MLA-017					Y							Y	Y		Y				Y	Y				Y							Y		Y
PFAS	4:2 fluorotelomer sulfonate (4:2 PFAS)	SGS AXYS MLA-081	MLA-081																															Y		Y
		SGS AXYS MLA-089	MLA-089												Y	Y																				
	4:2 Fluorotelomersulfonate (4:2 FTS)	SGS AXYS MLA-110	MLA-110					Y																			Y									
	4:2 fluorotelomersulfonate (4:2 PFAS)	SGS AXYS MLA-110	MLA-110			Y																			Y											

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	6:2 fluorotelomer sulfonate (6:2 PFAS)	SGS AXYS MLA-081	MLA-081																															Y		Y
		SGS AXYS MLA-089	MLA-089												Y	Y																				
	6:2 Fluorotelomersulfonate (6:2 FTS)	SGS AXYS MLA-110	MLA-110					Y																			Y									
	6:2 fluorotelomersulfonate (6:2 PFAS)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	8:2 fluorotelomer sulfonate (8:2 PFAS)	SGS AXYS MLA-081	MLA-081																															Y		Y
		SGS AXYS MLA-089	MLA-089												Y	Y																				
	8:2 Fluorotelomersulfonate (8:2 FTS)	SGS AXYS MLA-110	MLA-110					Y																			Y									
	8:2 fluorotelomersulfonate (8:2 PFAS)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	N-Ethylperfluorooctanesulfonamide (N-EtFOSA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	N-Ethylperfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	N-Ethylperfluorooctanesulfonamidoethanol (N-EtFOSE)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	N-Methylperfluorooctanesulfonamide (N-MeFOSA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	N-Methylperfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	N-Methylperfluorooctanesulfonamidoethanol (N-MeFOSE)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorobutanesulfonate (PFBS)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorobutanoate (PFBA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorodecanesulfonate (PFDS)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorodecanoate (PFDA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorodecanoate (PFDA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluorododecanesulfonate (PFDoS)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorododecanoate (PFDoA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluoroheptanesulfonate (PFHpS)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	Perfluoroheptanoate (PFHpA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorohexanesulfonate (PFHxS)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorohexanoate (PFHxA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorohexanoate (PFHxA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluorononanesulfonate (PFNS)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorononanoate (PFNA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorononanoate (PFNA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluorooctane sulfonamide (PFOSA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluorooctanesulfonamide (PFOSA), a.k.a FOSA	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorooctanesulfonate (PFOS)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp: CALA	Serum: CALA	Solids: CALA	Solids: California DPH	Solids: Florida DOH	Solids: Minnesota DOH	Solids: New Jersey DEP	Solids: New York DOH	Solids: Virginia DGS	Solids: Washington DE	Solids: Maine DOH	Solids: ANAB	Solids: DoD	Tissue: CALA	Tissue: Florida DOH	Tissue: Minnesota DOH	Tissue: New Jersey DEP	Tissue: Virginia DGS	Tissue: ANAB	Tissue: DoD	Urine: CALA	Water: CALA	Water, Non-Potable: California DPH	Water, Non-Potable: Florida DOH	Water, Non-Potable: Minnesota DOH	Water, Non-Potable: New Jersey DEP	Water, Non-Potable: New York DOH	Water, Non-Potable: Virginia DGS	Water, Non-Potable: Washington DE *	Water, Non-Potable: Maine DOH	Water, Non-Potable: ANAB	Water, Non-Potable: Pennsylvania DEP	Water, Non-Potable: DoD
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorooctanoate (PFOA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluorooctanoate (PFOA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluoropentanesulfonate (PFPeS)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluoropentanoate (PFPeA)	SGS AXYS MLA-110	MLA-110			Y																			Y											
	Perfluoropentanoate (PFPeA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110					Y																			Y									
	Perfluorotetradecanoate (PFTeDA)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluorotridecanoate (PFTrDA)	SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
	Perfluoroundecanoate (PFUnA)	EPA 537 modified	MLA-041												Y	Y																				
			MLA-043																			Y	Y													
			MLA-060																															Y		Y
		SGS AXYS MLA-060	MLA-060																						Y		Y	Y	Y					Y		Y
		SGS AXYS MLA-041	MLA-041			Y		Y	Y	Y					Y	Y																				
		SGS AXYS MLA-043	MLA-043														Y	Y	Y	Y		Y	Y													
		SGS AXYS MLA-042	MLA-042		Y																															
		SGS AXYS MLA-110	MLA-110			Y		Y																	Y		Y									
PPCP	1,7-Dimethylxanthine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	10-hydroxy-amitriptyline	SGS AXYS MLA-075	MLA-075			Y																			Y											
	2-hydroxy-ibuprofen	SGS AXYS MLA-075	MLA-075			Y																			Y											
	4-Epianhydrochlortetracycline (EACTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	4-Epianhydrotetracycline (EATC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	4-Epichlortetracycline (ECTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	4-Epioxytetracycline (EOTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	4-Epitetracycline (ETC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Acetaminophen	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Albuterol	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Alprazolam	SGS AXYS MLA-075	MLA-075			Y																			Y											

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
				CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	Amitriptyline	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Amlodipine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Amphetamine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Anhydrochlortetracycline (ACTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Anhydrotetracycline (ATC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Atenolol	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Atorvastatin	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Azithromycin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Benzoylecgonine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Benztropine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Betamethasone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Bisphenol A	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Caffeine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Carbadox	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Carbamazepine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Cefotaxime	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Chlortetracycline (CTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Cimetidine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Ciprofloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Clarithromycin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Clinafloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Clonidine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Cloxacillin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Cocaine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Codeine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Cotinine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	DEET (N,N-diethyl-m-toluamide)	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Dehydronifedipine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Demeclocycline	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Desmethyldiltiazem	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Diazepam	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Digoxigenin	EPA 1694	MLA-075											Y																			Y			

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Digoxin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Diltiazem	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Diphenhydramine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Doxycycline	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Enalapril	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Enrofloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Erythromycin	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Erythromycin anydrate	EPA 1694	MLA-075											Y																			Y			
	Flumequine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Fluocinonide	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Fluoxetine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Fluticasone propionate	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Furosemide	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Gemfibrozil	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Glipizide	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Glyburide	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Hydrochlorothiazide	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Hydrocodone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Hydrocortisone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Ibuprofen	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Isochlortetracycline (ICTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Lincomycin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Lomefloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Meprobamate	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Metformin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Methylprednisolone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Metoprolol	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Miconazole	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Minocycline	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Naproxen	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Norfloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Norfluoxetine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Norgestimate	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Norverapamil	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Ofloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Ormetoprim	EPA 1694	MLA-075											Y																			Y			

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Method	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Oxacillin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Oxolinic acid	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Oxycodone	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Oxytetracycline (OTC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Paroxetine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Penicillin G	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Penicillin V	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Prednisolone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Prednisone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Promethazine	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Propoxyphene	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Propranolol	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Ranitidine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Roxithromycin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sarafloxacin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sertraline	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Simvastatin	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfachloropyridazine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfadiazine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfadimethoxine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfamerazine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfamethazine	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfamethizole	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfamethoxazole	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfanilamide	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Sulfathiazole	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Tetracycline (TC)	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Theophylline	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Thiabendazole	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Trenbolone	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Trenbolone acetate	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Triamterene	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Triclocarban	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Triclosan	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	Trimethoprim	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Tylosin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Valsartan	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Verapamil	SGS AXYS MLA-075	MLA-075			Y																			Y											
	Virginiamycin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
	Warfarin	EPA 1694	MLA-075											Y																			Y			
		SGS AXYS MLA-075	MLA-075			Y																			Y											
Targeted Metabolites	11, 14, 17-eicosatrienoic acid (eicosatrienoic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	11, 14-eicosadienoic acid	SGS AXYS MLM-001	MLM-001														Y																			
	3-hydroxytyrosine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Acetylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Acetylornithine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Alanine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	alpha-Aminoadipic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Arginine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Asparagine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Aspartate	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Asymmetric dimethylarginine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Butenylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Butyrylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	C22:5 ISOMER 1 (tentatively all-cis-4, 8, 12, 15, 19-docosapentaenoic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	C22:5 ISOMER 2 (all-cis-7,10,13,16,19-docosapentaenoic acid (DPA)	SGS AXYS MLM-001	MLM-001														Y																			
	C22:5 ISOMER 3 (tentatively all-cis-4, 7, 10, 13, 16-docosapentaenoic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Carnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Carnosine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	chenodeoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	cholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Citrulline	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Creatinine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Decadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	decanoic acid (capric acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Decanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Decenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	deoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	docosahexaenoic acid (DHA)	SGS AXYS MLM-001	MLM-001														Y																			
	docosatetraenoic acid (adrenic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Dodecanedioylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Dodecanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Dodecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Dopamine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	eicosapentaenoic acid (EPA)	SGS AXYS MLM-001	MLM-001														Y																			
	Eicosatetraenoic acid (arachidonic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	eicosatrienoic acid (dihomo-γ-linolenic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Glutaconylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Glutamate	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Glutamine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Glutarylcarnitine (Hydroxyhexanoylcarnitine)	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Glycine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	glycochenodeoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	glycocholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	glycodeoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hexadecadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	hexadecanoic acid (palmitic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Hexadecanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	hexadecenoic acid (palmitoleic acid)	SGS AXYS MLM-001	MLM-001														Y																			

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	Hexadecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hexanoylcarnitine (Fumarylcarnitine)	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hexenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hexose (sum isomers)	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Histamine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Histidine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyhexadecadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyhexadecanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyhexadecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxylbutyrylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyoctadecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyproline	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxypropionylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxysphingomyeline C14:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxysphingomyeline C16:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxysphingomyeline C22:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxysphingomyeline C22:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxysphingomyeline C24:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxytetradecadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxytetradecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Hydroxyvalerylcarnitine (Methylmalonylcarnitine)	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Isoleucine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Kynurenine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Leucine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lithocholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Lysine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C14:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C16:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C16:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C17:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C18:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C18:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C18:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C20:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C20:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C24:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C26:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C28:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	lysoPhosphatidylcholine acyl C28:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Methionine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Methioninesulfoxide	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Methylglutarylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Nitrotyrosine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Nonaylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	octadecadienoic acid (linoleic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Octadecadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	octadecanoic acid (stearic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Octadecanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	octadecatrienoic acid (γ-linolenic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Octadecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Octanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Ornithine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phenylalanine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phenylethylamine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C30:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C30:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C30:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C32:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

Compound Class	Compound	Accredited Method ID	SGS AXYS Method	Pulp: CALA	Serum: CALA	Solids: CALA	Solids: California DPH	Solids: Florida DOH	Solids: Minnesota DOH	Solids: New Jersey DEP	Solids: New York DOH	Solids: Virginia DGS	Solids: Washington DE	Solids: Maine DOH	Solids: ANAB	Solids: DoD	Tissue: CALA	Tissue: Florida DOH	Tissue: Minnesota DOH	Tissue: New Jersey DEP	Tissue: Virginia DGS	Tissue: ANAB	Tissue: DoD	Urine: CALA	Water: CALA	Water, Non-Potable: California DPH	Water, Non-Potable: Florida DOH	Water, Non-Potable: Minnesota DOH	Water, Non-Potable: New Jersey DEP	Water, Non-Potable: New York DOH	Water, Non-Potable: Virginia DGS	Water, Non-Potable: Washington DE *	Water, Non-Potable: Maine DOH	Water, Non-Potable: ANAB	Water, Non-Potable: Pennsylvania DEP	Water, Non-Potable: DoD
	Phosphatidylcholine acyl-alkyl C32:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C34:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C34:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C34:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C34:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C36:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C38:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C40:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C42:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C44:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C44:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C44:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine acyl-alkyl C44:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C24:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C26:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C28:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C30:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C30:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C32:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C32:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C32:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C32:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C34:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C34:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C34:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C34:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C36:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C38:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C38:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C38:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C38:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C38:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD
	Phosphatidylcholine diacyl C38:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C40:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:4	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:5	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Phosphatidylcholine diacyl C42:6	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Pimelylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Proline	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Propenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Propionylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Putrescine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sarcosine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Serine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Serotonin	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Spermidine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Spermine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C16:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C16:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C18:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C18:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C20:2	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C22:3	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C24:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C24:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C26:0	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Sphingomyeline C26:1	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Symmetric dimethylarginine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Taurine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	taurochenodeoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	taurocholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	taurodeoxycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	taurolithocholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	tauroursodexoycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Tetradecadienylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	tetradecanoic acid (myristic acid)	SGS AXYS MLM-001	MLM-001														Y																			
	Tetradecanoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Tetradecenoylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Threonine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Tiglylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Total dimethylarginine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Tryptophan	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Tyrosine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	ursodexoycholic acid	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Valerylcarnitine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
	Valine	SGS AXYS MLM-001	MLM-001		Y												Y							Y												
TBBPA	Tetrabromobisphenol A	SGS AXYS MLA-079	MLA-079		Y																															

Accreditation Scope

SGS AXYS Analytical Services Ltd.
(formerly AXYS Analytical Services Ltd.)
file ref.: ACC-101 Rev. 35

				Pulp	Serum	Solids											Tissue							Urine	Water	Water, Non-Potable										
Compound Class	Compound	Accredited Method ID	SGS AXYS Metho	CALA	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE	Maine DOH	ANAB	DoD	CALA	Florida DOH	Minnesota DOH	New Jersey DEP	Virginia DGS	ANAB	DoD	CALA	CALA	California DPH	Florida DOH	Minnesota DOH	New Jersey DEP	New York DOH	Virginia DGS	Washington DE *	Maine DOH	ANAB	Pennsylvania DEP	DoD

Note*
Analysis of pesticides and PCBs in non-potable water samples by AXYS method MLA-007, with the exception of NPDES or State permitted discharges and Stormwater applications, may fall within the scope of Washington State Department of Ecology solids matrix accreditation, subject to approval of the Ecology Project Manager.

Legend

Y	Accreditation scope
BFR	Brominated flame retardants (non-PBDPE)
BPA and mPE	Bisphenol A and mono-Phthalate Esters
HBCDD	Hexabromocyclododecane
OC Pesticides	Organochlorine Pesticides
PAH	Polycyclic Aromatic Hydrocarbons
PBDPE	Polybrominated diphenylethers
PCB	Polychlorinated Biphenyls
PCDDF	Polychlorinated dibenzodioxins/furans
PFAS	Per- and Polyfluoroalkyl Substances
PPCP	Pharmaceutical and Personal Care Products
TBBPA	Tetrabromobisphenol A
California DPH	California Department of Public Health, Lab ID 2911 (target analytes shown are those approved 2014)
Florida DOH	Florida Department of Health, Lab ID E871007, (NELAC Standard)
Pennsylvania DEP	Pennsylvania Department of Environmental Protection
Minnesota DOH	Minnesota Department of Health, Lab ID 232-999-430, (NELAC Standard)
New Jersey DEP	New Jersey Department of Environmental Protection, Lab ID CANA005, (NELAC Standard)
New York DOH	New York Department of Health, Lab ID 11674, (NELAC Standard)
Washington DE	Washington Department of Ecology, Lab ID C404
Virginia DGS	Virginia Department of General Services, Division of Consolidated Laboratory Services, Lab ID 460224, (NELAC Standard)
Maine DOH	Maine Center for Disease Control and Prevention, Department of Health and Human Services, Lab ID CN00003
DoD	US Department of Defense
CALA	Canadian Association for Laboratory Accreditation Inc., Lab ID A2637, (ISO/IEC 17025:2005 Standard)
ANAB	ANSI-ASQ National Accreditation Board, certificate ADE-1861, (ISO/IEC 17025:2005 and US DOD Standards)

CALA Testing Accreditation No. A 2637

ANAB ACCREDITED ISO/IEC 17025 DOD ELAP Certificate ADE-1861

Hatfield Consultants
ATTN: Meghan Isaacs
200 - 850 Harbourside Drive
North Vancouver BC V7P 0A3

Date Received: 23-OCT-17
Report Date: 27-MAR-18 13:28 (MT)
Version: FINAL REV. 3

Client Phone: 604-926-3621

Certificate of Analysis

Lab Work Order #: L2011667
Project P.O. #: NOT SUBMITTED
Job Reference:
C of C Numbers:
Legal Site Desc:

Comments: ADDITIONAL 19-JAN-18 09:37

Dana Brown, Chem. Tech. DIPL
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2011667-1 JCL-1							
Sampled By: CLIENT on 17-OCT-17 @ 11:30							
Matrix: comp							
ABT1 BTEX + Styrene, F1 to F4							
BTEX and F1							
Benzene	0.0130		0.0050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Toluene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Ethylbenzene	0.015		0.010	mg/kg	17-OCT-17	30-OCT-17	R3865022
m+p-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
o-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Styrene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Xylenes	<0.10		0.10	mg/kg	17-OCT-17	30-OCT-17	R3865022
Surrogate: 1,4-Difluorobenzene (SS)	90.4		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 4-Bromofluorobenzene (SS)	85.7		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 3,4-Dichlorotoluene (SS)	86.5		70-130	%	17-OCT-17	30-OCT-17	R3865022
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	82.3		70-130	%	26-OCT-17	26-OCT-17	R3870980
Chrom. to baseline at nC50	NO				26-OCT-17	26-OCT-17	R3870980
Prep/Analysis Dates					26-OCT-17	26-OCT-17	R3870980
CCME Total Hydrocarbons							
F1 (C6-C10)	11		10	mg/kg		01-NOV-17	
F1-BTEX	11		10	mg/kg		01-NOV-17	
F2 (C10-C16)	110	DLHM	40	mg/kg		01-NOV-17	
F3 (C16-C34)	1500	DLHM	40	mg/kg		01-NOV-17	
F4 (C34-C50)	1160	DLHM	40	mg/kg		01-NOV-17	
F4G-SG (GHH-Silica)	6920		500	mg/kg		01-NOV-17	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	3.03		0.40	%		01-NOV-17	
Total Carbon by combustion method							
Total Carbon by Combustion	11.7		0.05	%	31-OCT-17	31-OCT-17	R3871926
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.364		0.050	%		01-NOV-17	R3871794
Total Organic Carbon Calculation							
Total Organic Carbon	11.3		0.050	%		01-NOV-17	
Miscellaneous Parameters							
% Moisture	64.6		0.50	%		25-OCT-17	R3867265
F4G Prep/Analysis Dates					26-OCT-17	01-NOV-17	R3872325
Mercury (Hg)	0.0357		0.0050	mg/kg	20-JAN-18	22-JAN-18	R3941812
Particle Size Analysis:Mini-Pipet Method							
% Sand (2.0mm - 0.05mm)	16.6		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Silt (0.05mm - 2um)	70.0		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Clay (<2um)	13.4		1.0	%	31-OCT-17	01-NOV-17	R3871878
Texture	Silt loam				31-OCT-17	01-NOV-17	R3871878
Metals in Soil by CRC ICPMS							
Aluminum (Al)	5860		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Antimony (Sb)	<0.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Arsenic (As)	3.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Barium (Ba)	82.8		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Beryllium (Be)	0.39		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Bismuth (Bi)	<0.20		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Boron (B)	11.1		5.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cadmium (Cd)	0.164		0.020	mg/kg	03-NOV-17	03-NOV-17	R3874018
Calcium (Ca)	12900		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Chromium (Cr)	11.0		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cobalt (Co)	6.15		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2011667-1 JCL-1							
Sampled By: CLIENT on 17-OCT-17 @ 11:30							
Matrix: comp							
Metals in Soil by CRC ICPMS							
Copper (Cu)	8.66		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Iron (Fe)	15600		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lead (Pb)	5.87		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lithium (Li)	6.8		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Magnesium (Mg)	3570		20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Manganese (Mn)	489		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Molybdenum (Mo)	0.50		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Nickel (Ni)	12.4		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Phosphorus (P)	517		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Potassium (K)	830		100	mg/kg	03-NOV-17	03-NOV-17	R3874018
Selenium (Se)	0.25		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Silver (Ag)	<0.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sodium (Na)	170		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Strontium (Sr)	41.7		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sulfur (S)	6800		1000	mg/kg	03-NOV-17	03-NOV-17	R3874018
Thallium (Tl)	0.088		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tin (Sn)	<2.0		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Titanium (Ti)	34.2		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tungsten (W)	<0.50		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Uranium (U)	0.847		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Vanadium (V)	19.6		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zinc (Zn)	40.5		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zirconium (Zr)	7.6		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
L2011667-2 JCL-2							
Sampled By: CLIENT on 17-OCT-17 @ 13:45							
Matrix: comp							
ABT1 BTEX + Styrene, F1 to F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Toluene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Ethylbenzene	<0.010		0.010	mg/kg	17-OCT-17	30-OCT-17	R3865022
m+p-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
o-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Styrene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Xylenes	<0.10		0.10	mg/kg	17-OCT-17	30-OCT-17	R3865022
Surrogate: 1,4-Difluorobenzene (SS)	91.9		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 4-Bromofluorobenzene (SS)	90.1		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 3,4-Dichlorotoluene (SS)	81.7		70-130	%	17-OCT-17	30-OCT-17	R3865022
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	81.2		70-130	%	26-OCT-17	26-OCT-17	R3870980
Chrom. to baseline at nC50	NO				26-OCT-17	26-OCT-17	R3870980
Prep/Analysis Dates					26-OCT-17	26-OCT-17	R3870980
CCME Total Hydrocarbons							
F1 (C6-C10)	12		10	mg/kg		01-NOV-17	
F1-BTEX	12		10	mg/kg		01-NOV-17	
F2 (C10-C16)	36		20	mg/kg		01-NOV-17	
F3 (C16-C34)	293		20	mg/kg		01-NOV-17	
F4 (C34-C50)	197		20	mg/kg		01-NOV-17	
F4G-SG (GHH-Silica)	1330		500	mg/kg		01-NOV-17	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2011667-2 JCL-2							
Sampled By: CLIENT on 17-OCT-17 @ 13:45							
Matrix: comp							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	1.28		0.40	%		01-NOV-17	
Total Carbon by combustion method							
Total Carbon by Combustion	3.32		0.05	%	31-OCT-17	31-OCT-17	R3871926
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.154		0.050	%		01-NOV-17	R3871794
Total Organic Carbon Calculation							
Total Organic Carbon	3.17		0.050	%		01-NOV-17	
Miscellaneous Parameters							
% Moisture	40.7		0.50	%		25-OCT-17	R3867265
F4G Prep/Analysis Dates					26-OCT-17	01-NOV-17	R3872325
Mercury (Hg)	0.0178		0.0050	mg/kg	20-JAN-18	22-JAN-18	R3941812
Particle Size Analysis:Mini-Pipet Method							
% Sand (2.0mm - 0.05mm)	59.0		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Silt (0.05mm - 2um)	17.2		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Clay (<2um)	23.8		1.0	%	31-OCT-17	01-NOV-17	R3871878
Texture	Sandy clay loam				31-OCT-17	01-NOV-17	R3871878
Metals in Soil by CRC ICPMS							
Aluminum (Al)	5300		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Antimony (Sb)	0.12		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Arsenic (As)	2.04		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Barium (Ba)	49.9		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Beryllium (Be)	0.34		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Bismuth (Bi)	<0.20		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Boron (B)	6.0		5.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cadmium (Cd)	0.063		0.020	mg/kg	03-NOV-17	03-NOV-17	R3874018
Calcium (Ca)	4390		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Chromium (Cr)	9.56		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cobalt (Co)	3.81		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Copper (Cu)	6.09		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Iron (Fe)	10500		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lead (Pb)	4.29		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lithium (Li)	5.3		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Magnesium (Mg)	2240		20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Manganese (Mn)	196		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Molybdenum (Mo)	0.35		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Nickel (Ni)	8.77		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Phosphorus (P)	261		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Potassium (K)	780		100	mg/kg	03-NOV-17	03-NOV-17	R3874018
Selenium (Se)	<0.20		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Silver (Ag)	<0.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sodium (Na)	90		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Strontium (Sr)	21.4		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sulfur (S)	1600		1000	mg/kg	03-NOV-17	03-NOV-17	R3874018
Thallium (Tl)	0.072		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tin (Sn)	<2.0		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Titanium (Ti)	50.9		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tungsten (W)	<0.50		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Uranium (U)	0.411		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Vanadium (V)	16.7		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zinc (Zn)	19.6		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zirconium (Zr)	7.9		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2011667-3 LIT-1							
Sampled By: CLIENT on 17-OCT-17 @ 13:00							
Matrix: comp							
ABT1 BTEX + Styrene, F1 to F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Toluene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Ethylbenzene	<0.010		0.010	mg/kg	17-OCT-17	30-OCT-17	R3865022
m+p-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
o-Xylene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Styrene	<0.050		0.050	mg/kg	17-OCT-17	30-OCT-17	R3865022
Xylenes	<0.10		0.10	mg/kg	17-OCT-17	30-OCT-17	R3865022
Surrogate: 1,4-Difluorobenzene (SS)	76.9		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 4-Bromofluorobenzene (SS)	71.2		70-130	%	17-OCT-17	30-OCT-17	R3865022
Surrogate: 3,4-Dichlorotoluene (SS)	74.1		70-130	%	17-OCT-17	30-OCT-17	R3865022
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	78.9		70-130	%	26-OCT-17	26-OCT-17	R3870980
Chrom. to baseline at nC50	NO				26-OCT-17	26-OCT-17	R3870980
Prep/Analysis Dates					26-OCT-17	26-OCT-17	R3870980
CCME Total Hydrocarbons							
F1 (C6-C10)	<10		10	mg/kg		01-NOV-17	
F1-BTEX	<10		10	mg/kg		01-NOV-17	
F2 (C10-C16)	20		20	mg/kg		01-NOV-17	
F3 (C16-C34)	580		20	mg/kg		01-NOV-17	
F4 (C34-C50)	484		20	mg/kg		01-NOV-17	
F4G-SG (GHH-Silica)	3320		500	mg/kg		01-NOV-17	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	1.32		0.40	%		01-NOV-17	
Total Carbon by combustion method							
Total Carbon by Combustion	4.42		0.05	%	31-OCT-17	31-OCT-17	R3871926
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.159		0.050	%		01-NOV-17	R3871794
Total Organic Carbon Calculation							
Total Organic Carbon	4.26		0.050	%		01-NOV-17	
Miscellaneous Parameters							
% Moisture	50.6		0.50	%		25-OCT-17	R3867265
F4G Prep/Analysis Dates					26-OCT-17	01-NOV-17	R3872325
Mercury (Hg)	0.0129		0.0050	mg/kg	20-JAN-18	22-JAN-18	R3941812
Particle Size Analysis:Mini-Pipet Method							
% Sand (2.0mm - 0.05mm)	70.2		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Silt (0.05mm - 2um)	23.0		1.0	%	31-OCT-17	01-NOV-17	R3871878
% Clay (<2um)	6.8		1.0	%	31-OCT-17	01-NOV-17	R3871878
Texture	Sandy loam				31-OCT-17	01-NOV-17	R3871878
Metals in Soil by CRC ICPMS							
Aluminum (Al)	2210		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Antimony (Sb)	<0.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Arsenic (As)	1.26		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Barium (Ba)	36.5		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Beryllium (Be)	0.15		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Bismuth (Bi)	<0.20		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Boron (B)	6.5		5.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cadmium (Cd)	0.063		0.020	mg/kg	03-NOV-17	03-NOV-17	R3874018
Calcium (Ca)	4310		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Chromium (Cr)	4.56		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Cobalt (Co)	2.14		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2011667-3 LIT-1							
Sampled By: CLIENT on 17-OCT-17 @ 13:00							
Matrix: comp							
Metals in Soil by CRC ICPMS							
Copper (Cu)	3.04		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Iron (Fe)	6500		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lead (Pb)	2.12		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Lithium (Li)	<2.0		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Magnesium (Mg)	1150		20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Manganese (Mn)	335		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Molybdenum (Mo)	0.26		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Nickel (Ni)	4.99		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Phosphorus (P)	215		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Potassium (K)	380		100	mg/kg	03-NOV-17	03-NOV-17	R3874018
Selenium (Se)	<0.20		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Silver (Ag)	<0.10		0.10	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sodium (Na)	72		50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Strontium (Sr)	20.4		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Sulfur (S)	1400		1000	mg/kg	03-NOV-17	03-NOV-17	R3874018
Thallium (Tl)	<0.050		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tin (Sn)	<2.0		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Titanium (Ti)	31.9		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Tungsten (W)	<0.50		0.50	mg/kg	03-NOV-17	03-NOV-17	R3874018
Uranium (U)	0.309		0.050	mg/kg	03-NOV-17	03-NOV-17	R3874018
Vanadium (V)	7.96		0.20	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zinc (Zn)	13.0		2.0	mg/kg	03-NOV-17	03-NOV-17	R3874018
Zirconium (Zr)	2.3		1.0	mg/kg	03-NOV-17	03-NOV-17	R3874018

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLHM	Detection Limit Adjusted: Sample has High Moisture Content

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
BTXS,F1-MEOH-ED	Soil	BTEX and F1	EPA 8260C/5021A and CWS PHC Tier 1

This analysis involves the extraction of a subsample of the sediment/soil with methanol added in the field at the time of subsampling. The soil methanol extract is added to water and reagents, then heated in a sealed vial to equilibrium. The headspace from the vial is transferred into a gas chromatograph. BTX Target compound concentrations are measured using mass spectrometry detection. The instrumental portion of F1 analysis is carried out in accordance with the Canada Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method (2001).

ALS Test Code	Matrix	Test Description	Method Reference**
C-TIC-PCT-SK	Soil	Total Inorganic Carbon in Soil	CSSS (2008) P216-217

A known quantity of acetic acid is consumed by reaction with carbonates in the soil. The pH of the resulting solution is measured and compared against a standard curve relating pH to weight of carbonate.

ALS Test Code	Matrix	Test Description	Method Reference**
C-TOC-CALC-SK	Soil	Total Organic Carbon Calculation	CSSS (2008) 21.2

Total Organic Carbon (TOC) is calculated by the difference between total carbon (TC) and total inorganic carbon. (TIC)

ALS Test Code	Matrix	Test Description	Method Reference**
C-TOT-LECO-SK	Soil	Total Carbon by combustion method	CSSS (2008) 21.2

The sample is ignited in a combustion analyzer where carbon in the reduced CO_2 gas is determined using a thermal conductivity detector.

ALS Test Code	Matrix	Test Description	Method Reference**
F1-4-CALC-ED	Soil	CCME Total Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

Hydrocarbon results are expressed on a dry weight basis.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.
In samples where BTEX and F1 were analyzed , F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:
1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:
1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

ALS Test Code	Matrix	Test Description	Method Reference**
F2-4-TMB-ED	Soil	CCME Total Extractable Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment" For C10 to C50 hydrocarbons (F2, F3, F4) and gravimetric heavy hydrocarbons (F4G-sg), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds. F2, F3 & F4 are analyzed by on-column GC/FID, and F4G-sg is analyzed gravimetrically.

Notes:
1. F2 (C10-C16): Sum of all hydrocarbons that elute between nC10 and nC16.
2. F3 (C16-C34): Sum of all hydrocarbons that elute between nC16 and nC34.
3. F4 (C34-C50): Sum of all hydrocarbons that elute between nC34 and nC50.
4. F4G: Gravimetric Heavy Hydrocarbons
5. F4G-sg: Gravimetric Heavy Hydrocarbons (F4G) after silica gel treatment.
6. Where F4 (C34-C50) and F4G-sg results are reported for a sample, the larger of the reported values is used for comparison against the relevant CCME standard for F4.
7. The gravimetric heavy hydrocarbon results (F4G-sg), cannot be added to the C6 to C50 hydrocarbon results.
8. This method is validated for use.
9. Data from analysis of quality control samples is available upon request.
10. Reported results are expressed as milligrams per dry kilogram.

ALS Test Code	Matrix	Test Description	Method Reference**
F4G-TMB-ED	Soil	CCME Gravimetric Heavy Hydrocarbons (SG)	CCME CWS-PHC, Pub #1310, Dec 2001
HG-200.2-CVAA-ED	Soil	Mercury in Soil by CVAAS	EPA 200.2/1631E (Mod)

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CVAAS.

IC-CACO3-CALC-SK	Soil	Inorganic Carbon as CaCO3 Equivalent	Calculation
MET-200.2-CCMS-ED	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A (mod)

This method uses a heated strong acid digestion with HNO3 and HCl and is intended to liberate metals that may be environmentally available. Silicate minerals are not solubilized. Dependent on sample matrix, some metals may be only partially recovered, including Al, Ba, Be, Cr, Sr, Ti, Tl, V, W, and Zr. Volatile forms of sulfur (including sulfide) may not be captured, as they may be lost during sampling, storage, or digestion. Analysis is by Collision/Reaction Cell ICPMS.

PREP-MOISTURE-ED	Soil	% Moisture	Oven dry 105C-Gravimetric

The weighed portion of soil is placed in a 105 C oven to dry to a constant weight; the drying time will vary based on the moisture content of the soil. The dried soil weight is then used to calculate % moisture.

Reference: ASTM D2974-00.

PSA-1-SK	Soil	Particle Size Analysis:Mini-Pipet Method	SSIR-51 Method 3.2.1

Dry, < 2 mm soil is treated with sodium hexametaphosphate to ensure complete dispersion of primary soil particles. The homogenized suspension is allowed to settle in accordance with Stoke's Law so that only clay particles remain in suspension.To determine the clay fraction, an aliquot of the clay suspension is removed, then dried and weighed. The sand fraction is determined by wet sieving the remaining suspension, then drying and weighing the sand retained on the sieve. The silt fraction is determined by calculation where % Silt = 100 - (%Sand+%Clay)

Reference:
Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

Kalra, Y.P., Maynard, D.G. 1991. Methods manual for forest soil and plant analysis. Forestry Canada. p. 42-45.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Client: Hatfield Consultants
200 - 850 Harbourside Drive
North Vancouver BC V7P 0A3

Contact: Meghan Isaacs

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BTXS,F1-MEOH-ED	Soil							
Batch R3865022								
WG2650494-4 DUP		**L2011667-1**						
Benzene		0.0130	0.0055	J	mg/kg	0.0075	0.01	30-OCT-17
Toluene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	30-OCT-17
Ethylbenzene		0.015	0.013		mg/kg	18	30	30-OCT-17
m+p-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	30-OCT-17
o-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	30-OCT-17
Styrene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	30-OCT-17
WG2650494-2 LCS								
Benzene			97.6		%		70-130	30-OCT-17
Toluene			91.6		%		70-130	30-OCT-17
Ethylbenzene			80.5		%		70-130	30-OCT-17
m+p-Xylene			89.0		%		70-130	30-OCT-17
o-Xylene			90.1		%		70-130	30-OCT-17
Styrene			94.8		%		70-130	30-OCT-17
WG2650494-1 MB								
Benzene			<0.0050		mg/kg		0.005	30-OCT-17
Toluene			<0.050		mg/kg		0.05	30-OCT-17
Ethylbenzene			<0.010		mg/kg		0.01	30-OCT-17
m+p-Xylene			<0.050		mg/kg		0.05	30-OCT-17
o-Xylene			<0.050		mg/kg		0.05	30-OCT-17
Styrene			<0.050		mg/kg		0.05	30-OCT-17
Surrogate: 1,4-Difluorobenzene (SS)			95.6		%		70-130	30-OCT-17
Surrogate: 4-Bromofluorobenzene (SS)			85.7		%		70-130	30-OCT-17
Surrogate: 3,4-Dichlorotoluene (SS)			106.4		%		70-130	30-OCT-17
WG2650494-5 MS		**L2011667-2**						
Benzene			92.4		%		50-140	30-OCT-17
Toluene			91.6		%		50-140	30-OCT-17
Ethylbenzene			90.3		%		50-140	30-OCT-17
m+p-Xylene			94.8		%		50-140	30-OCT-17
o-Xylene			101.7		%		50-140	30-OCT-17
Styrene			92.6		%		50-140	30-OCT-17
C-TIC-PCT-SK	Soil							
Batch R3871794								
WG2650564-1 DUP		**L2011667-3**						
Inorganic Carbon		0.159	0.154		%	3.1	20	01-NOV-17
WG2650564-2 LCS								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TIC-PCT-SK	Soil							
Batch R3871794								
WG2650564-2 LCS								
Inorganic Carbon			97.3		%		80-120	01-NOV-17
WG2650564-3 MB								
Inorganic Carbon			<0.050		%		0.05	01-NOV-17
C-TOT-LECO-SK	Soil							
Batch R3871926								
WG2650413-2 IRM		**08-109_SOIL**						
Total Carbon by Combustion			100.3		%		80-120	31-OCT-17
WG2650413-3 MB								
Total Carbon by Combustion			<0.05		%		0.05	31-OCT-17
F2-4-TMB-ED	Soil							
Batch R3870980								
WG2648380-3 IRM		**ALS PHC2 RM**						
F2 (C10-C16)			87.3		%		70-130	26-OCT-17
F3 (C16-C34)			95.7		%		70-130	26-OCT-17
F4 (C34-C50)			102.2		%		70-130	26-OCT-17
WG2648380-2 LCS								
F2 (C10-C16)			108.6		%		70-130	26-OCT-17
F3 (C16-C34)			105.8		%		70-130	26-OCT-17
F4 (C34-C50)			104.7		%		70-130	26-OCT-17
WG2648380-1 MB								
F2 (C10-C16)			<20		mg/kg		20	26-OCT-17
F3 (C16-C34)			<20		mg/kg		20	26-OCT-17
F4 (C34-C50)			<20		mg/kg		20	26-OCT-17
Surrogate: 2-Bromobenzotrifluoride			81.8		%		70-130	26-OCT-17
F4G-TMB-ED	Soil							
Batch R3872325								
WG2654676-2 IRM		**ALS PHC2 RM**						
Gravimetric Heavy Hydrocarbons (Silica)			94.3		%		70-130	01-NOV-17
WG2654676-1 MB								
Gravimetric Heavy Hydrocarbons (Silica)			<500		mg/kg		500	01-NOV-17
HG-200.2-CVAA-ED	Soil							
Batch R3941812								
WG2702155-3 CRM		**TILL-1_SOIL**						
Mercury (Hg)			88.8		%		70-130	22-JAN-18
WG2702155-2 LCS								
Mercury (Hg)			102.0		%		70-130	22-JAN-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-200.2-CVAA-ED	Soil							
Batch R3941812								
WG2702155-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	22-JAN-18
MET-200.2-CCMS-ED	Soil							
Batch R3874018								
WG2655835-3 CRM		**TILL-1_SOIL**						
Aluminum (Al)			93.6		%		70-130	03-NOV-17
Antimony (Sb)			125.3		%		70-130	03-NOV-17
Arsenic (As)			98.7		%		70-130	03-NOV-17
Barium (Ba)			92.8		%		70-130	03-NOV-17
Beryllium (Be)			102.6		%		70-130	03-NOV-17
Bismuth (Bi)			109.6		%		70-130	03-NOV-17
Boron (B)			5.3		mg/kg		0-8.2	03-NOV-17
Cadmium (Cd)			95.5		%		70-130	03-NOV-17
Calcium (Ca)			93.8		%		70-130	03-NOV-17
Chromium (Cr)			96.8		%		70-130	03-NOV-17
Cobalt (Co)			97.0		%		70-130	03-NOV-17
Copper (Cu)			98.2		%		70-130	03-NOV-17
Iron (Fe)			96.6		%		70-130	03-NOV-17
Lead (Pb)			102.2		%		70-130	03-NOV-17
Lithium (Li)			100.0		%		70-130	03-NOV-17
Magnesium (Mg)			100.2		%		70-130	03-NOV-17
Manganese (Mn)			96.5		%		70-130	03-NOV-17
Molybdenum (Mo)			102.6		%		70-130	03-NOV-17
Nickel (Ni)			98.1		%		70-130	03-NOV-17
Phosphorus (P)			103.4		%		70-130	03-NOV-17
Potassium (K)			89.5		%		70-130	03-NOV-17
Selenium (Se)			0.35		mg/kg		0.11-0.51	03-NOV-17
Silver (Ag)			0.25		mg/kg		0.13-0.33	03-NOV-17
Sodium (Na)			93.9		%		70-130	03-NOV-17
Strontium (Sr)			93.6		%		70-130	03-NOV-17
Tin (Sn)			1.1		mg/kg		0-3.1	03-NOV-17
Titanium (Ti)			88.0		%		70-130	03-NOV-17
Tungsten (W)			0.18		mg/kg		0-0.66	03-NOV-17
Uranium (U)			102.0		%		70-130	03-NOV-17

ALS Environmental

Quality Control Report

Workorder: L2011667 Report Date: 27-MAR-18

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R3874018								
WG2655835-3 CRM		**TILL-1_SOIL**						
Vanadium (V)			96.0		%		70-130	03-NOV-17
Zinc (Zn)			95.8		%		70-130	03-NOV-17
Zirconium (Zr)			0.9		mg/kg		0-1.8	03-NOV-17
WG2655835-2 LCS								
Aluminum (Al)			100.2		%		80-120	03-NOV-17
Antimony (Sb)			105.4		%		80-120	03-NOV-17
Arsenic (As)			103.1		%		80-120	03-NOV-17
Barium (Ba)			98.8		%		80-120	03-NOV-17
Beryllium (Be)			108.8		%		80-120	03-NOV-17
Bismuth (Bi)			99.4		%		80-120	03-NOV-17
Boron (B)			100.1		%		80-120	03-NOV-17
Cadmium (Cd)			103.8		%		80-120	03-NOV-17
Calcium (Ca)			102.8		%		80-120	03-NOV-17
Chromium (Cr)			101.1		%		80-120	03-NOV-17
Cobalt (Co)			98.9		%		80-120	03-NOV-17
Copper (Cu)			100.3		%		80-120	03-NOV-17
Iron (Fe)			100.8		%		80-120	03-NOV-17
Lead (Pb)			101.8		%		80-120	03-NOV-17
Lithium (Li)			106.2		%		80-120	03-NOV-17
Magnesium (Mg)			106.9		%		80-120	03-NOV-17
Manganese (Mn)			100.9		%		80-120	03-NOV-17
Molybdenum (Mo)			103.2		%		80-120	03-NOV-17
Nickel (Ni)			100.1		%		80-120	03-NOV-17
Phosphorus (P)			109.3		%		80-120	03-NOV-17
Potassium (K)			104.2		%		80-120	03-NOV-17
Selenium (Se)			101.0		%		80-120	03-NOV-17
Silver (Ag)			110.9		%		80-120	03-NOV-17
Sodium (Na)			106.7		%		80-120	03-NOV-17
Strontium (Sr)			102.6		%		80-120	03-NOV-17
Sulfur (S)			113.5		%		80-120	03-NOV-17
Thallium (Tl)			101.1		%		80-120	03-NOV-17
Tin (Sn)			102.2		%		80-120	03-NOV-17
Titanium (Ti)			97.9		%		80-120	03-NOV-17
Tungsten (W)			103.8		%		80-120	03-NOV-17

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R3874018								
WG2655835-2 LCS								
Uranium (U)			105.7		%		80-120	03-NOV-17
Vanadium (V)			103.8		%		80-120	03-NOV-17
Zinc (Zn)			95.1		%		80-120	03-NOV-17
Zirconium (Zr)			99.9		%		80-120	03-NOV-17
WG2655835-1 MB								
Aluminum (Al)			<50		mg/kg		50	03-NOV-17
Antimony (Sb)			<0.10		mg/kg		0.1	03-NOV-17
Arsenic (As)			<0.10		mg/kg		0.1	03-NOV-17
Barium (Ba)			<0.50		mg/kg		0.5	03-NOV-17
Beryllium (Be)			<0.10		mg/kg		0.1	03-NOV-17
Bismuth (Bi)			<0.20		mg/kg		0.2	03-NOV-17
Boron (B)			<5.0		mg/kg		5	03-NOV-17
Cadmium (Cd)			<0.020		mg/kg		0.02	03-NOV-17
Calcium (Ca)			<50		mg/kg		50	03-NOV-17
Chromium (Cr)			<0.50		mg/kg		0.5	03-NOV-17
Cobalt (Co)			<0.10		mg/kg		0.1	03-NOV-17
Copper (Cu)			<0.50		mg/kg		0.5	03-NOV-17
Iron (Fe)			<50		mg/kg		50	03-NOV-17
Lead (Pb)			<0.50		mg/kg		0.5	03-NOV-17
Lithium (Li)			<2.0		mg/kg		2	03-NOV-17
Magnesium (Mg)			<20		mg/kg		20	03-NOV-17
Manganese (Mn)			<1.0		mg/kg		1	03-NOV-17
Molybdenum (Mo)			<0.10		mg/kg		0.1	03-NOV-17
Nickel (Ni)			<0.50		mg/kg		0.5	03-NOV-17
Phosphorus (P)			<50		mg/kg		50	03-NOV-17
Potassium (K)			<100		mg/kg		100	03-NOV-17
Selenium (Se)			<0.20		mg/kg		0.2	03-NOV-17
Silver (Ag)			<0.10		mg/kg		0.1	03-NOV-17
Sodium (Na)			<50		mg/kg		50	03-NOV-17
Strontium (Sr)			<0.50		mg/kg		0.5	03-NOV-17
Sulfur (S)			<1000		mg/kg		1000	03-NOV-17
Thallium (Tl)			<0.050		mg/kg		0.05	03-NOV-17
Tin (Sn)			<2.0		mg/kg		2	03-NOV-17
Titanium (Ti)			<1.0		mg/kg		1	03-NOV-17

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R3874018								
WG2655835-1 MB								
Tungsten (W)			<0.50		mg/kg		0.5	03-NOV-17
Uranium (U)			<0.050		mg/kg		0.05	03-NOV-17
Vanadium (V)			<0.20		mg/kg		0.2	03-NOV-17
Zinc (Zn)			<2.0		mg/kg		2	03-NOV-17
Zirconium (Zr)			<1.0		mg/kg		1	03-NOV-17
PREP-MOISTURE-ED	Soil							
Batch R3867265								
WG2648599-5 LCS								
% Moisture			100.6		%		90-110	25-OCT-17
WG2648599-4 MB								
% Moisture			<0.50		%		0.5	25-OCT-17
PSA-1-SK	Soil							
Batch R3871878								
WG2650861-2 IRM		**2017-PSA**						
% Sand (2.0mm - 0.05mm)			53.2		%		45.8-55.8	01-NOV-17
% Silt (0.05mm - 2um)			31.1		%		28.6-38.6	01-NOV-17
% Clay (<2um)			15.7		%		10.6-20.6	01-NOV-17
WG2650861-3 MB								
% Sand (2.0mm - 0.05mm)			100		%		105	01-NOV-17
% Silt (0.05mm - 2um)			<1.0		%		1	01-NOV-17
% Clay (<2um)			<1.0		%		1	01-NOV-17

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Metals							
Mercury in Soil by CVAAS							
	1	17-OCT-17 11:30	20-JAN-18 00:00	28	95	days	EHT
	2	17-OCT-17 13:45	20-JAN-18 00:00	28	94	days	EHT
	3	17-OCT-17 13:00	20-JAN-18 00:00	28	94	days	EHT

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L2011667 were received on 23-OCT-17 16:25.

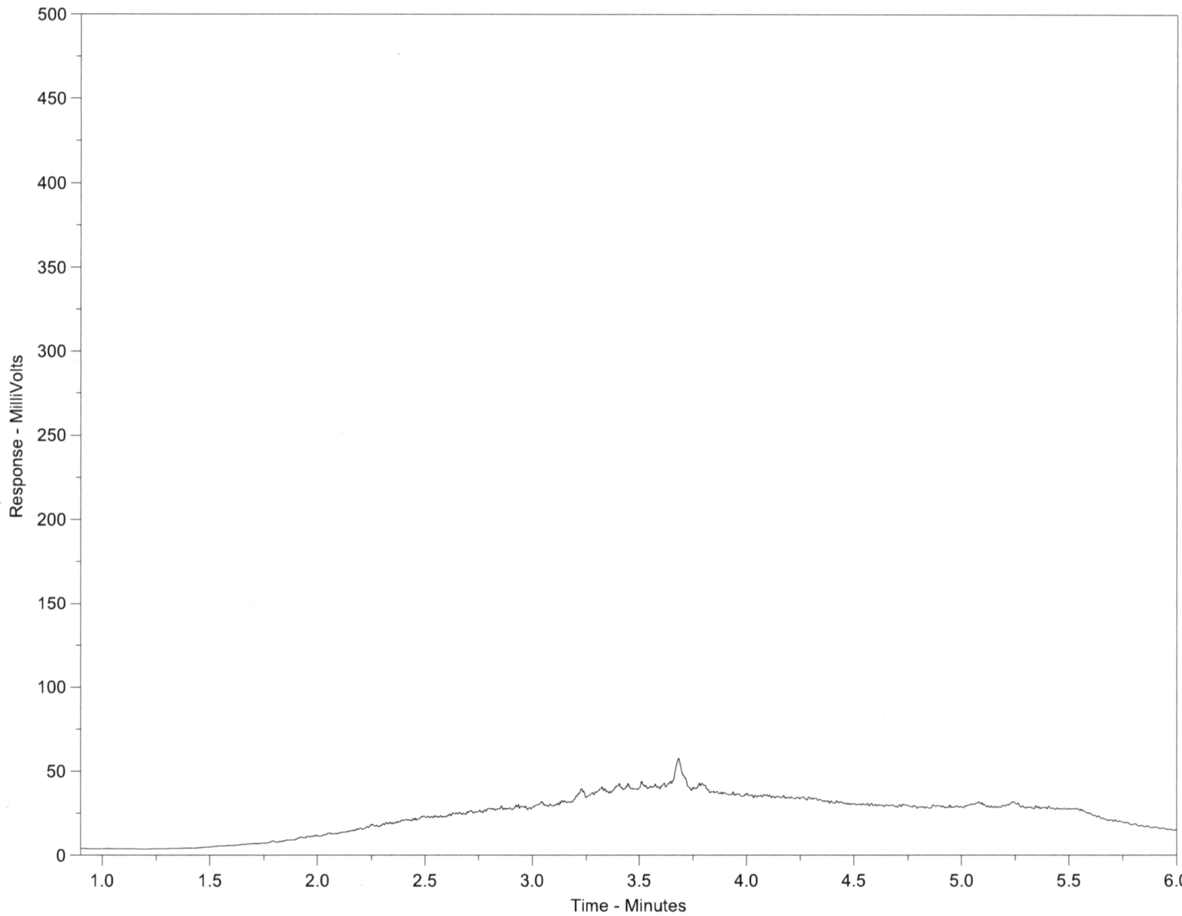
ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Hydrocarbon Distribution Report

ALS Sample ID: L2011667-1
Client ID: JCL-1



← F2 →	← F3 →	← F4 →	← > F4 →
nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline → ← Motor Oils/ Lube Oils/ Grease →

← Diesel/ Jet Fuels →

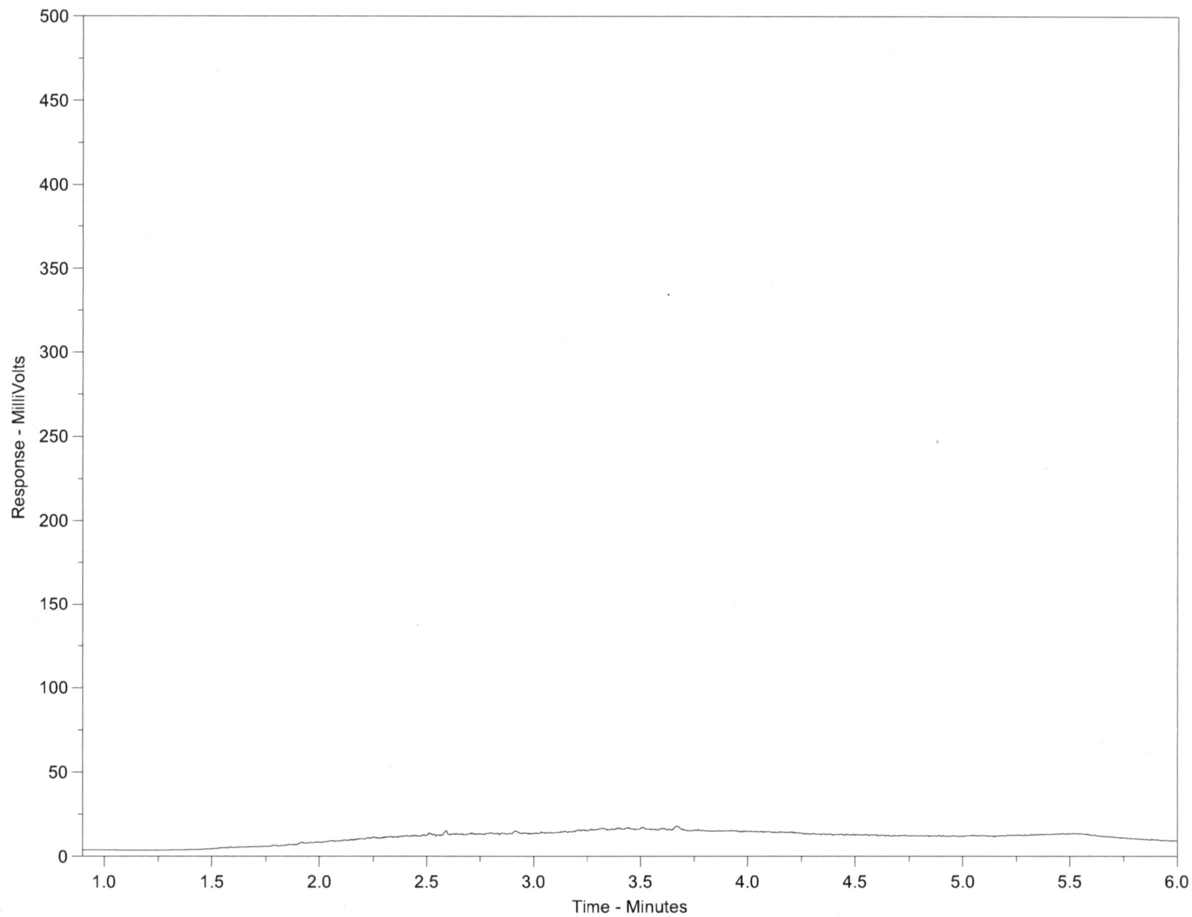
The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

Hydrocarbon Distribution Report

ALS Sample ID: L2011667-2
Client ID: JCL-2



F2	F3	F4	F4
nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F
← Gasoline →		← Motor Oils/ Lube Oils/ Grease →	
← Diesel/ Jet Fuels →			

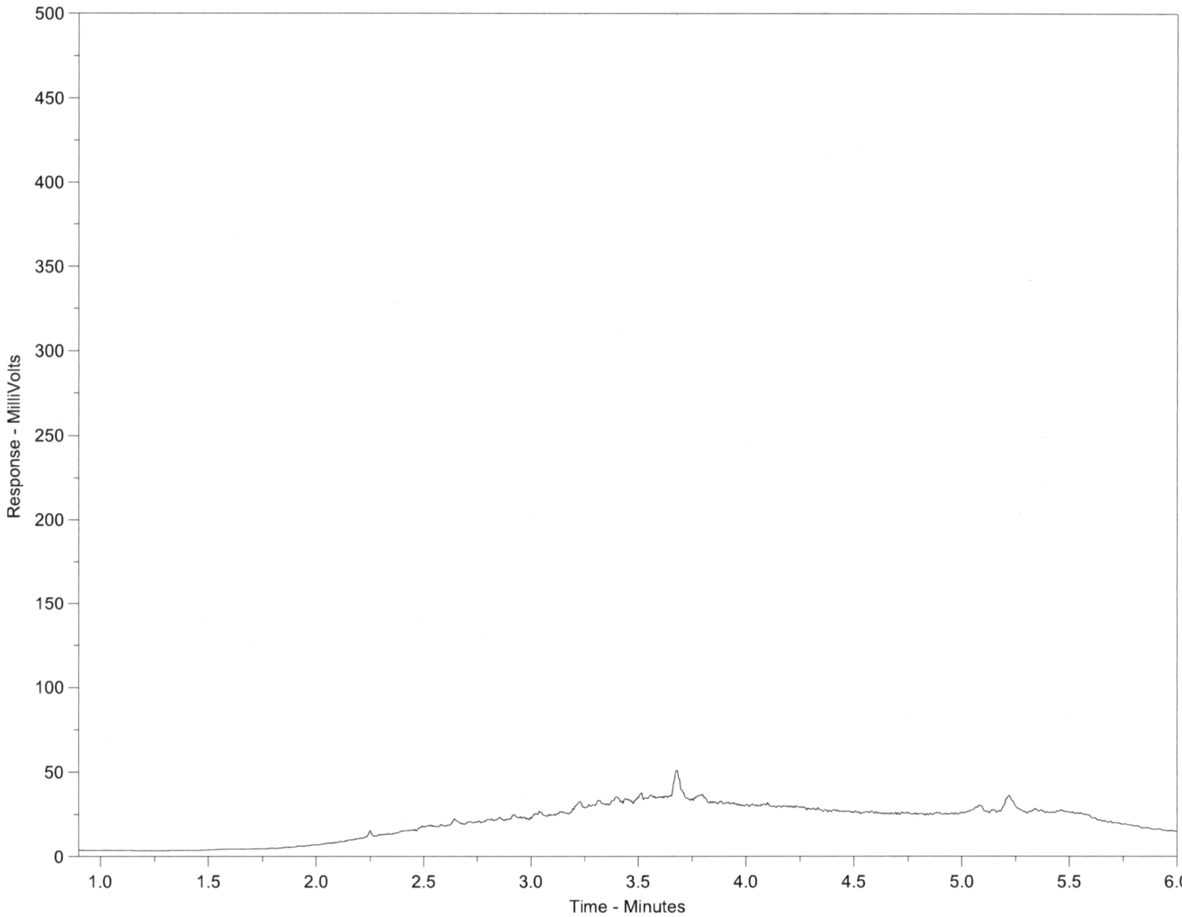
The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

Hydrocarbon Distribution Report

ALS Sample ID: L2011667-3
Client ID: LIT-1



← F2 →	← F3 →	← F4 →	← F4 →
nC10	nC16	nC34	nC50
174°C	287°C	481°C	575°C
346°F	549°F	898°F	1067°F
← Gasoline →		← Motor Oils/ Lube Oils/ Grease →	
← Diesel/ Jet Fuels →			

The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

Affix ALS barcode label here (lab use only)

COC Number: 14 -

Page ___ of ___

Report To: Meghan Isaacs
Company: Hatfield Consultants
Contact: Meghan Isaacs
Address: 200-850 Harbourside Dr North Vancouver BC V7P 0A3
Phone: (604) 926-3261

Invoice To: Same as Report To ☐ Yes ☐ No
Copy of Invoice with Report ☐ Yes ☐ No
Company: Hatfield Consultants
Contact: Daisy Nigai

Report Format / Distribution
Select Report Format: ☐ PDF ☐ EXCEL ☐ EDD (DIGITAL)
Quality Control (QC) Report with Report ☐ Yes ☐ No
☐ Criteria on Report - provide details below if box checked
Select Distribution: ☐ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax
Email 2

Invoice Distribution
Select Invoice Distribution: ☐ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax
Email 2

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)
R ☐ Regular (Standard TAT if received by 3 pm - business days)
P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge
Specify Date Required for E2,E or P:

Project Information
ALS Quote #:
Job #:
PO / AFE:
LSD:
ALS Lab Work Order # (lab use only)

Oil and Gas Required Fields (client use)
Approver ID: | Cost Center:
GL Account: | Routing Code:
Activity Code:
Location:
ALS Contact: | Sampler:

Analysis Request
Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	BTEX	CSA	Metals	Inorganic Carbon	TOC	Number of Containers
	JCL-1	17/10/17	11:30	Grab/Grab	/	/	/	/	/	5
	JCL-2	17/10/17	12:45	[illegible] Grab	-	-	/	/	/	4
	LIT-1	17/10/17	1300	Grab	/	-	/	/	/	4

L2011667-COFC

Drinking Water (DW) Samples[1] (client use)
Are samples taken from a Regulated DW System? ☐ Yes ☐ No
Are samples for human drinking water use? ☐ Yes ☐ No

Special Instructions / Specify Criteria to add on report (client Use)
Quote # QG4311
Some containers cracked on freezing and were discarded

SAMPLE CONDITION AS RECEIVED (lab use only)
Frozen ☐ SIF Observations Yes ☐ No ☐
Ice packs Yes ☐ No ☐ Custody seal intact Yes ☐ No ☐
Cooling Initiated ☐
INITIAL COOLER TEMPERATURES °C: -1
FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by: [redacted]	Date:	Time:	Received by: [redacted]	Date: Oct 23 17	Time: 4:25	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY — YELLOW - CLIENT COPY

NA-FM-0326e v09 Front/04 January 2014

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

Appendix A2.2

Sediment Toxicity Lab Reports

Maxxam
A Bureau Veritas Group Company

maxxam.ca

MAXXAM ANALYTICS
4606 Canada Way
Burnaby, BC V5G 1K5

Office 604 734 7276
Toll Free 800 665 8566
Fax 604 731 2386

FRESHWATER SEDIMENT TOXICITY TESTING USING *CHIRONOMUS DILUTUS* AND *HYALELLA AZTECA*

Prepared for:
Hatfield Consultants
200-850 Harbourside Dr.
North Vancouver, BC
Canada, V7P 0A3

Prepared by:
Ecotoxicology Group
Maxxam Analytics
Project No.: 2-11-17038
Maxxam Job #: B794914
December 2017

EXECUTIVE SUMMARY

Two freshwater sediment samples were collected on October 17, 2017. The samples arrived at Maxxam, in good condition, on October 25, 2017.

The following freshwater sediment toxicity tests were conducted on the samples; a 10 day survival and growth test with the freshwater midge, *Chironomus dilutus,* and a 14 day survival and growth test with the freshwater amphipod, *Hyalella azteca*.

Both the *Chironomus* test and the *Hyalella* test were initiated within their respective hold times with the *Hyalella* test ending on December 07, 2017 and the *Chironomus* test ending on December 01, 2017. All samples were statistically assessed against negative control for both tests.

Details regarding the test results, methods, test conditions, organism acclimation, and quality control measures are summarised within the report. All tabulated data, raw data, and associated supporting documents are located within the report appendices.

Each test was considered valid as survival and growth in the negative control(s) met the validity criteria outlined in the associated reference methods.

TABLE OF CONTENTS

LIST OF TABLES

SECTION

1 SEDIMENT DESCRIPTION

1.1 Sample Information

Two freshwater sediment samples were collected on October 17, 2017. The samples arrived at Maxxam, in good condition, on October 25, 2017.

Samples were collected separately for total organic carbon content, and moisture content. The data for these analyses were sent directly to the client, and are not included in this report. Grain size analysis was not requested by the client.

All tests were initiated within their respective hold times. Sample information, including sample descriptions, porewater ammonia analyses, and water quality data are located in Appendix A. Upon opening the sample containers, a description of each sample was recorded ("Sediment Sample Descriptions" in Appendix A).

Prior to testing, the sample was thoroughly homogenized, using a stainless steel spoon. Any headspace in the sample container was purged with nitrogen gas prior to re-sealing it in order to prevent oxidation of the sediment during storage. When not in use, the sediments were stored in the dark at 4 ± 2°C.

1.2 Negative Control Sediment

The control sediment (negative control) for the toxicity tests was collected from Yaquina Bay, Newport, Oregon, by staff of Northwestern Aquatic Sciences. This beach sand has been used as a negative control in previous studies within our laboratory, and has been found to be non-toxic to a variety of organisms. It was wet sieved through 500 µm stainless steel mesh and thoroughly washed with the appropriate control water before use in the tests.

Table 1-1 Physiochemical Characterisation of Yaquina Bay Beach Sand

Total Organic Carbon (mg/kg)	Moisture Content (%)	Sand (%)	Silt (%)	Clay (%)
<500	16	98	2.3	<2.0

1.3 Porewater Characterization

On Day -1 of *Chironomus* testing, a seventh replicate of each sample was prepared, filled with reconstituted control water and aerated overnight, along with the test vessels. The following morning, the overlying water in the seventh replicate of each sample was decanted and aliquots of the sediment were distributed into 500 mL polycarbonate bottles. Nitrogen gas was placed over the sediments prior to centrifuging for 20 minutes at ~5,000 rpm. The resulting porewater was carefully decanted and analysed for ammonia, pH, and temperature.

Analysis of ammonia in porewater was performed at the Maxxam Environmental Inorganic Water Laboratory. The total ammonia concentrations as N (mg/L) in the samples, was measured under basic conditions using the Berthelot reaction in the presence of EDTA. A sample was treated sequentially until a blue indophenol complex formed, which could then be measured photometrically at 660 nm.

Results of ammonia, temperature, and pH in porewater analyses for each of the test samples are available in Appendix A.

SECTION

2 10 DAY *CHIRONOMUS DILUTUS* SURVIVAL AND GROWTH TEST

2.1 Test Methods

The survival and growth of *Chironomus dilutus* larvae, when exposed to whole sediment samples for 10 days, was assessed according to the Maxxam Standard Operating Procedure: *Chironomus dilutus* 10-Day Survival and Growth Test (BBY2SOP-00010), which is based on the Environment Canada Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*) (EPS 1/RM/32).

One day prior to test initiation, the field replicates were individually homogenized, and a 100 mL aliquot was distributed into a 375 mL labelled test vessel. Reconstituted moderately hard water was then slowly added to the vessel by pouring a stream of water onto a Plexiglas baffle to minimize disturbing the sediment layer. The test vessels were then randomized on the bench top, and airlines and lids were fitted to each test vessel.

A composite sample was produced by combining equal portions of each field replicate. Then, 100 mL of the composite sample was distributed into a sixth and seventh replicate test vessels for water quality and porewater measurements.

The following day, aliquots of overlying water were removed from the test vessels for initial overlying water chemistry. The sixth replicate test vessel was used for water quality measurements for the duration of the test and the seventh replicate was decanted and centrifuged to extract porewater for ammonia, temperature, and pH measurements (see Section 1.3). To initiate the test, ten larval chironomids were randomly selected from their holding containers and directly seeded into the test vessels.

During the test, daily observations and aeration checks were performed. Temperature and dissolved oxygen measurements were taken three times per week in the test vessels designated for water quality measurements. Test vessels were also fed 3.75 mL Tetramin™ flakes, prepared as a 4 g dry solids/L slurry, on the days water quality measurements were taken.

At test termination, the contents of each test vessel were sieved through a 500 µm sieve in order to retrieve the live larval midges. The number of larvae found was recorded along with any other observations made. The organisms were then placed into pre-weighed aluminum weigh boats that were subsequently placed into a 60°C drying oven for >24hours. Missing chironomids were presumed to have died and decomposed during the test. Any larval midges that had reached the pupal or adult stage of development were excluded from the dry weight analysis.

2.2 Organism Information

2.2.1 Organism Acclimation and Holding Information

One batch of laboratory-reared *Chironomus dilutus* larvae was received from Aquatic Biosystems on November 21, 2017. The midge larvae were shipped in 1L plastic containers filled with unbleached paper towels and overlying moderately hard water. Prior to shipping, the headspace in each container was filled with oxygen gas of a sufficient concentration to maintain adequate saturation levels in the shipping water. They were shipped directly for overnight delivery to Maxxam and arrived without incident.

Upon arrival at Maxxam, the water quality of the shipping water was measured and compared to the test conditions. Gentle aeration was supplied to each shipping container. Any moribund or deceased larvae were removed and recorded on the acclimation sheet (Appendix B).

The chironomid larvae were not fed during the holding period as they were used the same day. Historically at Maxxam, it has been determined that little to no acclimation is required as long as the shipping, testing, and supplier laboratory conditions are similar.

2.2.2 Organism Health

The mortality rate during shipping did not exceed 10% overall. Bench sheets with the receiving water quality and observations of the number dead or inactive larvae are available in Appendix B.

2.2.3 Organism Age

At test initiation, 20 representative larvae were euthanized and their head capsule widths were measured to the nearest 0.1 mm, using an inverted microscope outfitted with an ocular micrometer. The average head capsule width of the organism batch was determined to within the 0.33 – 0.45 mm range, which indicated they were the recommended age (see Table 2-1).

2.3 Test Conditions

See Table 2-1 for a detailed list of the test conditions. All bench sheets used to record raw data are available in Appendix B.

Table 2-1 Test Conditions for the 10-day *Chironomus dilutus* Test

Parameter	Conditions and Methods
Test Type and Duration	10 Day, Static (non-renewal)
Temperature	Average daily temperature 23 ± 1 °C; instantaneous temperature 23 ± 3 °C.
Photoperiod and Light Intensity	16 hours light: 8 hours dark. Wide spectrum cool white fluorescent lights used to provide 664-737 lux.
Aeration	< 100 bubbles/ minute. Clean oil-free air supplied to each test vessel via micro-bore plastic tubing.
Test Chamber	375 mL glass jars with plastic lids containing small opening for airline tubing.
Sediment Volume	100 mL of homogenized sediment (3-4 cm depth).
Porewater Water Quality	Temperature, pH, and ammonia.
Overlying Water Source and Volume	175 mL (~5-6 cm depth); Reconstituted Moderately Hard Water; warmed to 23 ± 1°C and aerated >24 hours before use.
Overlying Water Quality	Temperature, pH, dissolved oxygen, conductance, hardness, alkalinity, and ammonia measurements on Day 0 and Day 10 of the test. Temperature and dissolved oxygen were also measured three times weekly during the test.
Replicates	5 replicates per sample, plus 2 additional replicates for water quality measurements and chemical analyses.
Control Sediment (Negative Control)	Yaquina Bay Sand, rinsed with control water and sieved through a 500 µm stainless steel mesh.
Reference Sediment	None
Feeding	3.75 mL Tetramin™ flakes as slurry (4g dry solids/L) per vessel, three times weekly.
Organisms/ replicate	10
Organism Source	Aquatic Biosystems, Fort Collins, Colorado.
Mortality during acclimation	0.0%
Mean Head capsule width and organism age	0.39 ± 0.09 mm; 3rd instar larval midges
Endpoints	Mean Survival and Growth
Test Validity Criteria	≥70% mean survival in the negative controls. >0.6 mg mean dry weight in the negative controls.
Statistical Software	CETIS™ version 1.9.2.4. Tidepool Scientific Software (Copyright 2009-2016).

2.4 Quality Assurance/Quality Control

2.4.1 Reference Toxicant Results

A 96 hour reference toxicant test, or positive control test, was conducted alongside the sediment test. The water-only test, using copper sulphate ($CuSO_4$), was initiated to aid in the assessment of organism sensitivity and the precision of the results. The resulting LC50 was then compared in a control chart against the results of previous tests. Table 2-2 summarises the result of the reference toxicant test.

The calculated LC50 for the reference toxicant test was within two standard deviations (95%) range of the historic mean LC50. This supports the assumption that the sensitivity of the organism batch was comparable to batches previously test in this laboratory.

A reference toxicant test is only one of the tools used to assess the health of an organism. Natural variability accounts for the spread in reference toxicant LC50s. The method used in preparing the control charts was based on from "Ecotoxicology Control Charting" (COR2WI-00002).

Table 2-2 Reference Toxicant Test Result for *Chironomus dilutus*

Organism Batch	Test Date	LC50 with 95% Confidence Limits (mg/L Cu^{2+})	Previous Mean with 2SD (mg/L Cu^{2+})
AB171121	2017 Nov 21	0.98 (0.77, 1.25)	0.83 (0.35, 1.97)

2.4.2 Test Validity Criteria

The test is considered to be acceptable if the mean percent survival in the negative control is ≥70%, and the mean dry weight is ≥ 0.6 mg. The mean percent survival of the negative controls was 100%, and the mean dry weight was 1.5 mg.

2.5 Results

Total survival and dry weights in each replicate, and mean ± standard deviation (SD) in the control and test sediments are listed in the "*Chironomus dilutus* Survival and Growth Test-Survival of Larvae" and the "Chironomid Survival and Growth Test- Dry Weights of Larvae" data sheets, respectively. A summary of the test results is presented in Table 2-3.

Total ammonia concentrations, pH, temperature, dissolved oxygen, hardness, conductance, and alkalinity measurements of the overlying water at test initiation (Day 0) and completion (Day 10) are available in Appendix B.

2.5.1 Data Analysis

The survival and dry weights data for all samples and the negative control was entered into the statistical program "Comprehensive Environmental Toxicity Information System" (CETIS™, 2009-2016). When determining the appropriate comparison tests to use, the Environment Canada "Guidance Document on Statistical Methods for Environmental Toxicity Tests" (EPS 1/RM/46, 2005) was followed.

See the CETIS™ Analytical Reports for information on the specific tests used for the mean survival and dry weight comparisons. Analyses between the negative control and samples were conducted as one-tailed comparisons. All analyses were performed with the decision level for determining statistical significance set to 0.05 (p value <0.05).

Table 2-3 Results for Mean *Chironomus dilutus* Survival and Growth

Sample ID	Mean Survival ± SD (%)	Mean Dry Weight ± SD (mg)
Negative Control	100 ± 0	1.53 ± 0.20
JCL-1	98 ± 4	1.28 ± 0.04*
JCL-2	94 ± 5	1.08 ± 0.15*

SD = Standard Deviation

*Indicates a statistically significant decrease in sample relative to the negative control.

2.6 Deviations

No deviations observed.

SECTION

3 14 DAY *HYALELLA AZTECA* SURVIVAL AND GROWTH TEST

3.1 Test Methods

The survival and growth of the freshwater amphipod, *Hyalella azteca*, when exposed to whole sediment samples for 14 days, were assessed according to the Maxxam SOP: *Hyalella azteca* 14-Day Survival and Growth Test (BBY2SOP-00011), which is based on the Environment Canada Biological Test Method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca* (EPS 1/RM/33).

One day prior to test initiation, the field replicates were individually homogenised, and a 100 mL aliquot was distributed into a 375 mL labelled test vessel. Reconstituted moderately hard water was then slowly added to the vessel by pouring a stream of water onto a Plexiglas baffle to minimize disturbing the sediment layer. The test vessels were then randomized on the bench top, and airlines and lids were fitted to each test vessel.

A composite sample was produced by combining equal portions of each field replicate. Then, 100 mL of the composite sample was distributed into a sixth replicate test vessel used for water quality measurements.

The following day, aliquots of overlying water were removed from the test vessels for initial overlying water chemistry. The sixth replicate test vessel was used for water quality measurements for the duration of the test. To initiate the test, the amphipods were removed from their holding containers and ten *Hyalella* were randomly selected and placed into plastic medicine cups containing control water. Once enough organisms were collected to start the tests they were seeded into the test vessels.

During the test, daily observations and aeration checks were performed. Temperature and dissolved oxygen measurements were taken three times per week in the test vessel designated for water quality measurements. Test vessels were also fed 800 µL per replicate of a ground Tetramin™ flake slurry (4 g dry solids/L) and 1.75 mL YCT (yeast, alfalfa flakes, and digested trout chow) on the days water quality measurements were taken.

At test termination, the contents of each test vessel were examined, a small portion at a time, in a glass pan on a light table. The live amphipods were collected and counted. The amphipods were then placed into aluminum foil weigh boats that were subsequently placed into a 60°C drying oven for >24hours. Missing amphipods were presumed to have died and decomposed during the test.

3.2 Organism Information

3.2.1 Acclimation and Holding Information

One batch of *Hyalella azteca* was received from Aquatic Biosystems, Fort Collins, Colorado, USA, on November 21, 2017. Laboratory reared juvenile amphipods were packed into 1L plastic containers, filled with moderately hard water and a few plastic mesh squares. Prior to shipping, the headspace in each container was filled with oxygen gas of a sufficient concentration to maintain adequate saturation levels in the shipping water. They were shipped directly for overnight delivery to Maxxam and arrived without incident.

Upon arrival at Maxxam, the container contents were carefully poured into glass culture dishes. Gentle aeration was supplied to each culture pan. An aliquot of shipping water from each container was set aside for water quality. It was then ensured that temperature adjustments to the holding water of the amphipods did not exceed 2°C per day.

The organisms were held at Maxxam for two days before the test was initiated. The amphipods were fed YCT and Tetramin™ slurry at organism arrival and before test initiation. Datasheets containing the water quality measurements, with observations of number dead or inactive amphipods during the holding period, are available in Appendix C.

3.2.2 Organism Health

The average mortality rate in the culture did not exceed 10%.

3.2.3 Organism Age

At test initiation, the amphipods were 7-9 days old.

3.3 Test Conditions

See Table 3-1 for a detailed list of the test conditions. All bench sheets and raw data are available in Appendix C.

Table 3-1 Test Conditions for the 14-day *Hyalella azteca* Test

Parameter	Conditions and Methods
Test Type and Duration	14 Day, Static
Temperature	Average daily temperature 23 ± 1 °C; instantaneous temperature 23 ± 3 °C.
Photoperiod and Light Intensity	16 hours light: 8 hours dark. Wide spectrum cool white fluorescent lights used to provide 664-737 lux.
Aeration	< 100 bubbles/ minute. Clean oil-free air supplied to each test vessel via micro-bore plastic tubing.
Test Chamber	375 mL glass jars with plastic lids containing small opening for airline tubing.
Sediment Volume	100 mL of homogenized sediment (3-4 cm depth).
Overlying Water Volume and Source	175 mL (~5-6 cm depth); Reconstituted water; SAM5 recipe (Borgmann, 1996). Temperature adjusted and aerated >24h before use.
Overlying Water Quality	Temperature, pH, dissolved oxygen, conductance, hardness, alkalinity, and ammonia measurements on Day 0 and Day 14 of the test.
Feeding	Every 2-3 days; 800 µL per replicate of a ground Tetramin™ flake slurry (4g dry solids/mL), and 1.75mL YCT.
Replicates	5 replicates per sample, plus an additional replicate for water quality measurements.
Control Sediment	Yaquina Bay sand rinsed with clean overlying water and sieved through a 500 µm stainless steel mesh.
Reference Sediment	None
Organisms/ Replicate	10
Organism Source and age	Aquatic Biosystems; amphipods aged 7-9 days at test start.
Mortality during acclimation	0.0%
Endpoints	Mean Survival, Mean Dry weight
Test Validity Criteria	≥ 80% mean survival in the controls. ≥0.1 mg/amphipod in the controls.
Statistical Software	CETIS™ version 1.9.2.4. Tidepool Scientific Software (Copyright 2009-2016).

3.4 Quality Assurance/Quality Control

3.4.1 Reference Toxicant Results

A 96 hour reference toxicant test, or positive control test, was conducted alongside the sediment test. The water-only test, using copper sulphate ($CuSO_4$) was initiated to aid in the assessment of organism sensitivity and the precision of the results. The reference toxicant test LC50 result was then compared in a control chart against the results of previous tests. Table 3-2 summarises the result of the reference toxicant test.

The calculated LC50 for the reference toxicant test was within the two standard deviation (95%) range of the historic mean LC50. This supports the assumption that the sensitivity of organism batch was comparable to batches previously tested in this laboratory.

A reference toxicant test is only one of the tools used to assess the health of an organism. Natural variability accounts for the spread in reference toxicant LC50s. The method used in preparing the control charts was based on from "Ecotoxicology Control Charting" (COR2WI-00002).

Table 3-2 Reference Toxicant Test Results for *Hyalella azteca*

Organism Batch	Test Date	LC50 with 95% Confidence Limits (µg/L Cu^{2+})	Previous Mean with 2SD (µg/L Cu^{2+})
AB171121	2017 Nov 23	307 (258, 366)	226 (161, 317)

3.4.2 Test Validity Criteria

Survival data in the negative control is considered to be acceptable if the mean percent survival in the negative control is ≥80%, and the mean dry weight in the negative control is ≥0.1 mg/amphipod. The mean percent survival of the negative control was 96% and the mean dry weight was 0.1 mg/amphipod.

3.5 Results

Total survival and dry weights in each replicate, and mean ± standard deviation (SD) in the control and test sediments are listed in the "*Hyalella azteca* Survival and Growth Test-Survival" and "*Hyalella azteca* Survival and Growth Test- Dry Weights" data sheets, respectively. A summary of the results is located in Table 3-3.

Total ammonia concentrations, pH, temperature, dissolved oxygen, hardness, conductance, and alkalinity measurements in the overlying water at test initiation (Day 0) and completion (Day 14) are available in Appendix C.

3.5.1 Data Analysis

The survival and dry weight data for all samples and the negative control was entered into the statistical program "Comprehensive Environmental Toxicity Information System" (CETIS™, 2009-2016). When determining the appropriate comparison tests to use, the Environment Canada "Guidance Document on Statistical Methods for Environmental Toxicity Tests" (EPS 1/RM/46, 2005) was followed.

See the CETIS™ Analytical Reports for information on the specific tests used for the mean survival and dry weight comparisons. A comparison analysis for all samples was conducted against the negative control. Analyses between the negative control and samples were conducted as one-tailed comparisons. All analyses were performed with the decision level for determining statistical significance set to 0.05 (p value <0.05).

Table 3-3 Results for Mean *Hyalella azteca* Survival and Growth

Sample ID	Mean Survival ± SD (%)	Mean Dry Weight ± SD (mg)
Negative Control	96 ± 9	0.13 ± 0.01
JCL-1	100 ± 0	0.15 ± 0.01
JCL-2	88 ± 11	0.09 ± 0.02*

SD = Standard Deviation

*Indicates a statistically significant decrease in sample relative to the negative control.

3.6 Deviations

No deviations observed.

SECTION 4 REFERENCES

Borgmann, U. 1996. Systematic Analysis of Aqueous Ion Requirements of *Hyalella azteca*: A Standard Artificial Medium Including the Essential Bromide Ion. Archives of Environmental Contamination and Toxicology. 30: 356-363.

Comprehensive Environmental Toxicity Information System (CETIS™). 2009-2016. Tidepool Scientific. LLC. Version 1.9.2.4

Environment Canada. 1997. Biological Test method: Test for Survival and Growth in Sediment of Freshwater Midges (*Chironomus tentans or Chironomus riparius*). Environmental Protection Publications, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/32.

Environment Canada. 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Publications. Conservation and Protection. Ottawa, Ontario. EPS 1/RM/46.

Environment Canada. 2013. Biological Test method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca*. Environmental Protection Publications, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/33.

Maxxam SOP for the *Chironomus dilutus* 10-Day Survival and Growth Test. BBY2SOP-00010.

Maxxam SOP for the *Hyalella azteca* 14-Day Survival and Growth Test. BBY2SOP-00011.

Maxxam WI for Ecotoxicology Control Charting. COR2 WI-00002.

APPENDICES

APPENDIX

A SAMPLE INFORMATION

Report Name: Entry

Job #: B794914

National Client: 1257, Hatfield Consultants

Client: HATFIELD CONSULTANTS
N. VANCOUVER
200-850 Harbourside Dr
North Vancouver, BC
Canada V7P 0A3

Report: same

Inv Attn: Accounts Payable-Daisy Ngai

Task Order:
Line Item:

Attention: Meghan Isaacs
Phone: (604)926 - 3261
Fax: (604)926 - 5389
EMAIL: misaacs@hatfieldgroup.com

Project Coordinator: GRR

Printed: 2017/12/20 Version 12
Reception Date: 2017/10/25
Reception Time: 12:19
Login Date: 2017/10/26
REQUIRED DATE: 2017/12/21, 18:00
Quote Number: B50166
P.O. Number:
Project Number: SHELL 8642
Site Location:
Site #:
Client Number: 99001
Rpt Address #:
Q.C Samples: No

Scenario: # 14830 Shell Compensation Lake Ecotox

Accounting Information
Desc. Code

Report Copies

Attention	# cop.	Fax	EMAIL
Dan Moats	0	6049265389	dmoats@hatfieldgroup.com
Ben Beall	0		bbeall@hatfieldgroup.com

Maxxam Number	Client Sample ID/Report ID	Cont's	Store Code	Recd. OK	Sampling Date	Matrix	Test Codes
SI0808-01R	JCL-1 JCL-1	5-OTHS	N/A-SO131	Yes	2017/10/17 11:30	SED	CHIROV-SD, DISPOSAL, ECOATTACHS HYALELV-SD, MOISTV-S, VSUBTOC-S
SI0809-01R	JCL-2 JCL-2	5-OTHS	N/A-SO131	Yes	2017/10/17 13:45	SED	CHIROV-SD, DISPOSAL, ECOATTACHS HYALELV-SD, MOISTV-S, VSUBTOC-S

Remarks: KR4. // LC,PA,CS by DB1// Oct 30, 2017//
[SubC Confirm: B7Q3658 TOC due 2017/11/29 -JWN-]

Inspected by: BP6
Date: 2017/10/26
Time: 10:45

Approved by: GRR
Date: 2017/11/20
Time: 14:08

Date of Sample Disposal:
Disposal by:

s.19(1)

Maxxam Analytics International Corporation o/a Maxxam Analytics
4606 Canada Way, Burnaby, British Columbia Canada V5G 1K5 Tel:(604) 734 7276 Toll-free:800-563-6266 Fax:(604) 731 2386 www.maxxam.ca

B794914_COC

INVOICE TO:		Report Information		Project Information	
Company Name	#99001 HATFIELD CONSULTANTS	Company Name		Quotation #	B50166
Contact Name	Accounts Payable-Daisy Ngai	Contact Name	Meghan Isaacs	P.O. #	
Address	200-850 Harbourside Dr	Address		Project #	SHELL 8642
	North Vancouver BC V7P 0A3			Project Name	
Phone	(604) 926-3261 x Fax: (604) 926-5389 x	Phone	Fax:	Site #	
Email		Email		Sampled By	

Page of
Bottle Order #: 635040
Project Manager
C#535040-02-01

Regulatory Criteria:
- [ ] CSR
- [ ] CCME
- [ ] BC Water Quality
- [ ] Other

Special Instructions

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects
Regular (Standard) TAT: (will be applied if Rush TAT is not specified): [ ]
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.
Job Specific Rush TAT (if applies to entire submission)
1 DAY [ ] 2 Day [ ] 3 Day [ ] Date Required: [ ]
Rush Confirmation Number: (call lab for #)

SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Metals Field Filtered ? (Y / N)	BIOASSAY - SEDIMENT (Chironomid 10d & Hyallela 14d)	# of Bottles	Comments
1		JCL-1	OCT 17/17	1130	Sed		✓	5	
2		JCL-2	OCT 17/17	1345	Sed		✓	5	
3									
4									
5									
6									
7									
8									
9									
10									

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
	17/10/23	3:Pm		2017/10/25	12:19	

Lab Use Only
Time Sensitive [ ] | Temperature (°C) on Receipt: 0,0,0 | Custody Seal Intact on Cooler? N/A Yes [ ] No [ ]

White: Maxxam Yellow: Client

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

Maxxam

ECOTOXICOLOGY

SEDIMENT SAMPLE DESCRIPTIONS

Client # / Name: 99001 - Hatfield

Job #: B794914

Maxxam Sample Name	Sample #	Client Sample Name	Date Homogenised / Subsampled	Grain Size & Colour	Type of Debris Removed (e.g. rock, wood, plant, etc...)	Endemic Animals Removed	Odour	Additional Comments/Observations	Analyst
JCL-1 A	SJ0808	JCL-1	2017 Nov 20 / 2017 Nov 22	Dark brown & silty	~~n/a~~ Ⓐ None	None	None	n/a	mo
JCL-1 B	SJ0808	JCL-1	2017 Nov 20 / 2017 Nov 22	Dark brown & silty	~~n/a~~ Ⓐ None	None	None	n/a	mo
JCL-1 C	SJ0808	JCL-1	2017 Nov 20 / 2017 Nov 22	Dark brown & silty	~~n/a~~ Ⓐ None	None	None	n/a	mo
JCL-1 D	SJ0808	JCL-1	2017 Nov 20 / 2017 Nov 22	Dark brown & silty	~~n/a~~ Ⓐ None	None	None	n/a	mo
JCL-1 E	SJ0808	JCL-1	2017 Nov 20 / 2017 Nov 22	Dark brown & silty	~~n/a~~ Ⓐ None	None	None	n/a	mo
JCL-2 A	SJ0809	JCL-2	2017 Nov 20 / 2017 Nov 22	Dark brown & ~~silty~~ Ⓐ clay-like	None	None	None	~~n/a~~ Ⓐ Small ~~brown~~ broken Ⓐ shells mixed in sediment	mo
JCL-2 B	SJ0809	JCL-2	2017 Nov 20 / 2017 Nov 22	Dark-brown & clay-like	None	None	None	Small ~~broken~~ Ⓐ broken shells mixed in sediment	mo
JCL-2 C	SJ0809	JCL-2	2017 Nov 20 / 2017 Nov 22	dark brown silty	large rock	None	None	Large rock	PH
JCL-2 D	SJ0809	JCL-2	2017 Nov 20 / 2017 Nov 22	~~Brown~~ Ⓐ Dark brown clay-like	Large rock	None	None	2 Large rocks, small broken shells mixed in sediment	mo
JCL-2 E	SJ0809	JCL-2	2017 Nov 20 / 2017 Nov 22	~~Brown~~ Dark Ⓐ brown silty	~~n/a~~ Ⓐ None	None	None	Sticks (~3 cm) in sediment	mo

Ⓐ WE mo 2017 Nov 20

ECOTOXICOLOGY

FRESHWATER SEDIMENT TESTS – POREWATER MEASUREMENTS

Client # & Name: **99001 Hatfield Consultants**

Date Measured: 2017 NOV 21

Method for Porewater Collection:
Spun each sediment sample at 5000 RPM for 20 mins at 4°C. After centrifuging, decanted off water sample and measured temperature, pH and sent subsamples for ammonia analysis.

Sample ID	Temperature (°C)	pH	Ammonia (mg/L)
Control	22.1	7.7	~~0.30~~ 0.30 (WE OMC 2017 DEC 20)
JCL-1	22.0	7.2	4.0
JCL-2	22.0	7.5	0.18
	2017 NOV 21		
Analyst	[signature]	[signature]	[signature]
Date	2017 NOV 21	2017 NOV 21	2017 NOV 21

Comments:
N/A

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B7A3503
Report Date: 2017/11/28

Maxxam Analytics (TOX Internal)
Client Project #: 99001 HATFIELD
Sampler Initials: MA

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		SN3371		SN3372		SN3373	
Sampling Date		2017/11/21		2017/11/21		2017/11/21	
COC Number		3683		3683		3683	
	UNITS	Control Day 0 Pore Water	RDL	JCL-1 Day 0 Pore Water	RDL	JCL-2 Day 0 Pore Water	RDL
Nutrients							
Total Ammonia (N)	mg/L	0.30	0.020	4.0 (1)	0.10	0.18	0.020

RDL = Reportable Detection Limit

(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

APPENDIX

B 10-DAY CHIRONOMUS DILUTUS SURVIVAL AND GROWTH TEST

CETIS Analytical Report

Report Date: 20 Dec-17 16:32 (p 1 of 1)
Test Code: CT-99001-0117 | 15-8720-1050

Chironomus 10-d Survival and Growth Sediment Test — **Maxxam**

Analysis ID:	21-2448-2678	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.9.2
Analyzed:	20 Dec-17 16:32	**Analysis:**	STP 2xK Contingency Tables	**Official Results:**	Yes

Batch ID:	19-9256-0924	**Test Type:**	Survival-AF Growth	**Analyst:**	
Start Date:	21 Nov-17 16:02	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Reconstituted Water
Ending Date:	01 Dec-17 12:00	**Species:**	Chironomus dilutus	**Brine:**	Not Applicable
Duration:	9d 20h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Fisher Exact/Bonferroni-Holm Test

Sample I	vs	Sample II	Test Stat	P-Type	P-Value	Decision(α:5%)
Control		JCL-1	0.5000	Exact	1.0000	Non-Significant Effect
		JCL-2	0.1212	Exact	0.1212	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.117	2.548	0.3274	No Outliers Detected

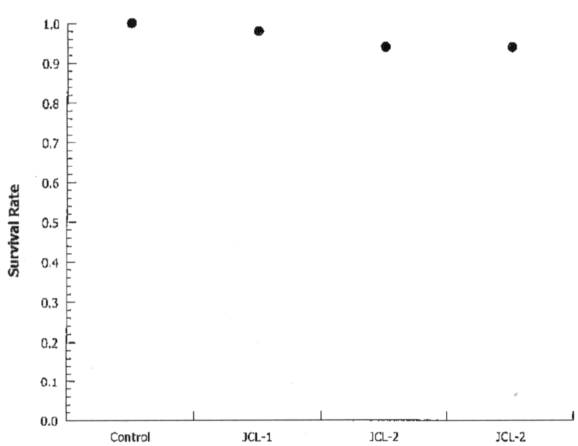
Data Summary

Group	Code	NR	R	NR + R	Prop NR	Prop R	%Effect
Control		50	0	50	1	0	0.0%
JCL-1		49	1	50	0.98	0.02	2.0%
JCL-2		47	3	50	0.94	0.06	6.0%

Survival Rate Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control		1.0000	1.0000	1.0000	1.0000	1.0000
JCL-1		1.0000	1.0000	1.0000	1.0000	0.9000
JCL-2		1.0000	0.9000	0.9000	0.9000	1.0000

Graphics



Analyst: 2017 Dec 20 [signature] QA: 2017 Dec 21 [signature]

CETIS Analytical Report

Report Date: 20 Dec-17 16:32 (p 1 of 2)
Test Code: CT-99001-0117 | 15-8720-1050

Chironomus 10-d Survival and Growth Sediment Test — Maxxam

Analysis ID:	11-5458-2565	**Endpoint:**	Mean Dry Weight	**CETIS Version:**	CETISv1.9.2
Analyzed:	20 Dec-17 16:32	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes
Batch ID:	19-9256-0924	**Test Type:**	Survival-AF Growth	**Analyst:**	
Start Date:	21 Nov-17 16:02	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Reconstituted Water
Ending Date:	01 Dec-17 12:00	**Species:**	Chironomus dilutus	**Brine:**	Not Applicable
Duration:	9d 20h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Data Transform	Alt Hyp	Comparison Result	PMSD
Untransformed	C > T	JCL-1 failed mean dry weight	13.01%
		JCL-2 failed mean dry weight	13.01%

Dunnett Multiple Comparison Test

Sample I	vs	Sample II	Test Stat	Critical	MSD	DF	P-Type	P-Value	Decision(α:5%)
Control		JCL-1*	2.622	2.108	0.199	8	CDF	0.0202	Significant Effect
		JCL-2*	4.72	2.108	0.199	8	CDF	4.7E-04	Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.045	2.548	0.4197	No Outliers Detected

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.498533	0.249266	2	11.18	0.0018	Significant Effect
Error	0.267473	0.0222894	12			
Total	0.766006		14			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance Test	6.349	9.21	0.0418	Equal Variances
Distribution	Shapiro-Wilk W Normality Test	0.9779	0.8328	0.9536	Normal Distribution

Mean Dry Weight Summary

Group	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
Control		5	1.53	1.278	1.783	1.463	1.282	1.813	0.09107	13.31%	0.00%
JCL-1		5	1.283	1.228	1.338	1.288	1.234	1.338	0.01976	3.44%	16.17%
JCL-2		5	1.085	0.8946	1.275	1.039	0.947	1.281	0.06848	14.12%	29.12%

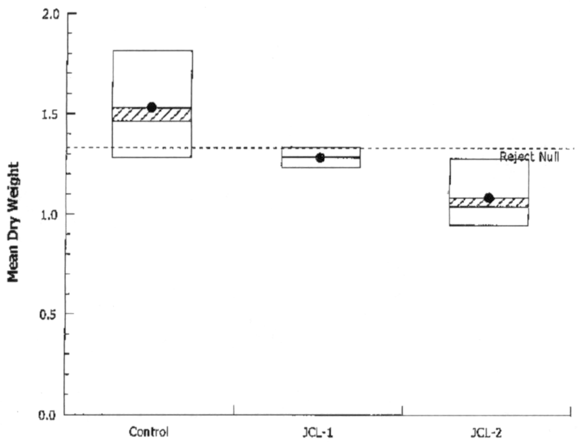
Mean Dry Weight Detail

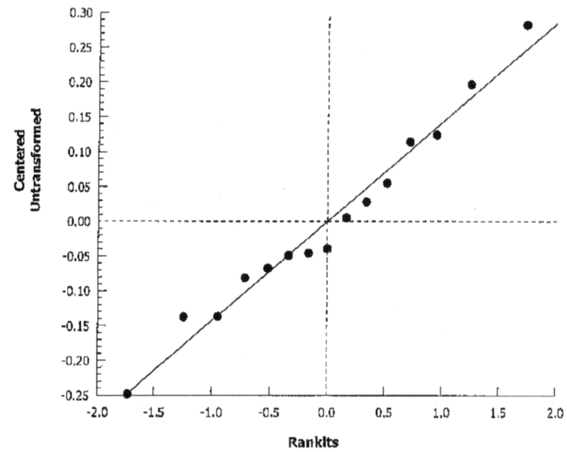
Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control		1.813	1.645	1.449	1.282	1.463
JCL-1		1.338	1.234	1.311	1.288	1.243
JCL-2		0.947	1.209	0.9478	1.281	1.039

Chironomus 10-d Survival and Growth Sediment Test — Maxxam

Analysis ID:	11-5458-2565	Endpoint:	Mean Dry Weight	CETIS Version:	CETISv1.9.2
Analyzed:	20 Dec-17 16:32	Analysis:	Parametric-Control vs Treatments	Official Results:	Yes

Graphics





Analyst: 2017 Dec 20 QA: MB 2017 Dec 21

ECOTOXICOLOGY ***Chironomus dilutus*** **Survival and Growth Test**

Survival of Larvae

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00271/3

Client # & Name: 99001 - Hatfield

Start Date and Time: 2017 Nov 21 @ 16:02

Job # B794914

End Date: 2017 Dec 01

Organism Lot #: AB171121

Analysts: M. O'toole, S. Rostama

Sample	Rep	Initial # Larvae	Final # Larvae	% Survived	Survival	
					Mean %	SD %
Control	A	10	10	100	100	0
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		
JCL-1	A	10	10	100	98	4
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	9	90		
JCL-2	A	10	10	100	94	5
	B	10	9	90		
	C	10	9	90		
	D	10	9	90		
	E	10	10	100		

Maxxam

ECOTOXICOLOGY

Chironomid Survival and Growth Test
Dry Weights of Larvae

BBY2FCD-00231/3

Client # & Name: 99001, Hatfield consultants
Start Date and Time: 2017 Nov 21 @ 16:02
Balance ID: BBY2-0260
End Date: 2017 Dec 01
Job # B794914
Weighing Dates: 2017 Nov 28, 2017 Dec 07
Drying Temperature (°C): 60
Drying Time (h) >24h
Analyst(s): N. Shergill, D. Lai

Boat #	Sample ID	Replicate	# Worms	Boat Wt. (g)	Boat & Worms Wt. (g)	Worm Wt. (mg)	Mean Wt. /Worm (mg)	Mean Wt. /Sample (mg)	SD
347	Control	A	10	1.09475	1.11288	18.13	1.81	1.53	0.20
348		B	10	1.08108	1.09753	16.45	1.64		
349		C	10	1.09977	1.11426	14.49	1.45		
350		D	10	1.09742	1.11024	12.82	1.28		
351		E	10	1.10783	1.12246	14.63	1.46		
352	JCL-1	A	10	1.07924	1.09262	13.38	1.34	1.28	0.04
353		B	10	1.08919	1.10153	12.34	1.23		
354		C	10	1.08810	1.10121	13.11	1.31		
355		D	10	1.12755	1.14043	12.88	1.29		
356		E	9	1.11646	1.12765	11.19	1.24		
357	JCL-2	A	10	1.10533	1.11480	9.47	0.95	1.08	0.15
358		B	9	1.10700	1.11788	10.88	1.21		
359		C	9	1.10995	1.11848	8.53	0.95		
360		D	9	1.10349	1.11502	11.53	1.28		
361		E	10	1.13846	1.14885	10.39	1.04		
362		QA/QC		1.0977	1.09757	-	-	-	-
363		QA/QC		1.11267	1.11253	-	-	-	-
347		0-A	10	1.09483	1.11290	18.07	-	-	-
		Analyst:		NS	DML				

The average dry weight for the replicate controls must be >0.6 mg, for the test to be valid.
Notes:

ECOTOXICOLOGY

***CHIRONOMUS DILUTUS* TEST DATA SHEET**

Sample ID:	Control	**Start Date:**	2017 Nov 21
Sample Date:	n/a	**End Date:**	2017 Dec 01
Sample Received:	n/a	**Job/Sample #:**	n/a

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.1	8.3	100	116	358	479	58.3	93.4	0.038	4.1

Initial overlying WQ measurements:	
Analyst mo	Date 2017 Nov 21

Final overlying WQ measurements:	
Analyst NB	Date 2017 Dec 01

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	22.3	23.4	23.1	23.1	22.2
D.O. (mg/L)	8.6	8.5	8.4	8.2 ✓	8.4
Feeding	✓	✓	✓	✓	
Analyst	mo	TW	NS	JT	NB

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	10
Analyst	mo	mo	mo	mo	mo

Date	Replicate	Comments	Analyst
2017 Nov 28	Measure	Did WQ on measure	JT

DMG 2017 Dec 20

ECOTOXICOLOGY

***CHIRONOMUS DILUTUS* TEST DATA SHEET**

Sample ID: JCL-1

Sample Date: 2017 Oct 17

Sample Received: 2017 Oct 25

Start Date: 2017 Nov 21

End Date: 2017 Dec 01

Job/Sample #: B794914/SI0808

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.1	8.2	124	136	376	399	828	823	0.74	0.84

Initial overlying WQ measurements:	
Analyst mo	Date 2017Nov21

Final overlying WQ measurements:	
Analyst NB	Date 2017 Dec 01

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.2	23.5	23.4	23.1	22.0
D.O. (mg/L)	8.3	8.4	8.5	8.3	8.4
Feeding	✓	✓	✓	✓	
Analyst	mo	TW	NB	J	NB

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	9
Analyst	mo	SR	mo	mo	mo

Date	Replicate	Comments	Analyst
2017Nov28	Measure	Did WQ on measure	J

DMC 2017 Dec20

ECOTOXICOLOGY
CHIRONOMUS DILUTUS TEST DATA SHEET

Sample ID:	JCL-2	Start Date:	2017 Nov 21
Sample Date:	2017 Oct 17	End Date:	2017 Dec 01
Sample Received:	2017 Oct 25	Job/Sample #:	B794914/SI0809

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.1	8.3	132	164	371	451	77.8	102	0.058	0.20

Initial overlying WQ measurements:	
Analyst mo	Date 2017Nov21

Final overlying WQ measurements:	
Analyst MB	Date 2017Dec01

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.2	23.5	23.1	23.2 ✓	22.2
D.O. (mg/L)	8.3	8.0	8.3	8.2 ✓	8.4
Feeding	✓	✓	✓	✓	
Analyst	mo	TW	NS	J	MB

Replicate	A	B	C	D	E
# Surviving	10	9	9	9	10
Analyst	SR	SR	mo	SR	mo

Date	Replicate	Comments	Analyst
2017Nov28	Measure	Did WQ on measure	J

DMC 2017 Dec20

Client # & Name	99001 Hatfield Consultants
Project Number	2-11-17038
Test Initiation Date	November 21, 2017 — Test Initiation Time: ~~1633~~ 1602
Test Completion Date	December 1, 2017
Statistics File #	CT-99001-0117
Analyst(s)	D.Lai, M.O'Toole, T.Wollelo, Armstrong, N.Shergill, N.Blassnitz, S.Rostami
Control Water Batch	2017 Nov 17
Control Sediment #1	Yaquina Bay Beach Sand
Control Sediment #2	~~DMC 2017 Dec20~~
Organism Lot	AB171121
Age at Start of Test	3rd instar
Feeding Regime	3.75 mL Tetrafin slurry per replicate 3x weekly
Food Preparation Date:	2017 Nov 03
Equipment IDs:	BBY2-0368
Job #	B794914
List of Sample ID/#	JCL-1/SI0808
	JCL-2/SI0809
	~~DMC 2017 Dec20~~
Additional Comments:	

ECOTOXICOLOGY

CHIRONOMID SURVIVAL AND GROWTH TEST – AERATION CHECKS

Client # & Name: 99001 Hatfield

Start Date & Time: 2017 Nov21 @ 16:02

Initial when aeration is checked. If air is off record DO and note which replicate(s) in comments section.

	Day -1	Day 0	1	2	3	4	5	6	7	8	9	10
Date	2017 Nov20	2017 Nov21	2017 Nov22	2017 Nov23	2017 Nov24	2017 Nov25	2017 Nov26	2017 Nov27	2017 Nov28	2017 Nov29	2017 Nov30	2017 Dec01
Early AM	(A) mo n/a	mo	mo	TW	TW	[initials]	NS	TW	[initials]	[initials]	[initials]	NB
Mid-day	n/a	mo	mo	TW	TW	[initials]	NS	TW	[initials]	[initials]	SR	DMC 2017 Dec20
Late PM	mo	DMC	mo	SR	[initials]	[initials]	NS	mo	SR	[initials]	[initials]	

Comments:

Aeration started @ 16:28 - mo 2017 Nov20

DMC 2017 Dec20

(A) WE mo 2017 Nov20

Chironomus dilutus (Formerly C. tentans)
Measurements of Head Capsule Widths

Client # & Name: 10025 + 99001

Start Date and Time: 2017 Nov 21

End Date: 2017 Dec 01

Organism Lot #: AB171121

Head Widths at Beginning of Test

Chironomid #	Head Width (mm)
1	0.40
2	0.39
3	0.38
4	0.35
5	0.35
6	0.35
7	0.40
8	0.40
9	0.32
10	0.65
11	0.33
12	0.35
13	0.33
14	0.35
15	0.60
16	0.35
17	0.33
18	0.36
19	0.39
20	0.35
Average	0.39
SD	0.09
Analyst	DML

Average must be 0.33-0.45 mm (Environment Canada 1998)
1 mm=40 units on micrometer

Proofed: NB 2017 Dec 21

ECOTOXICOLOGY

Chironomus dilutus (Formerly C. tentans)
Measurements of Head Capsule Widths

Maxxam

BBY2FCD-00247/1

Client # & Name: 10025 + 99001

Start Date and Time: 2017 Nov21

End Date: 2017 Dec01

Organism Lot #: AB171121

Head Widths at Beginning of Test

Chironomid #	Head Width (mm)
1	0.40
2	0.39
3	0.38
4	0.35
5	0.35
6	0.35
7	0.40
8	0.40
9	0.32
10	0.65
11	0.33
12	0.35
13	0.33
14	0.35
15	0.60
16	0.35
17	0.33
18	0.36
19	0.39
20	0.35
Average	#DIV/0!
SD	#DIV/0!
Analyst	DML

200uM = 2 ocular units (oc)

100uM = 1oc

.1mm = 1oc

Average must be 0.33-0.45 mm (Environment Canada 1998)
1 mm=40 units on micrometer

ECOTOXICOLOGY

ORGANISMS - ACCLIMATION AND HOLDING CONDITIONS

Maxxam
A Bureau Veritas Group Company

Client #'s: 99001, 10025
Date & Time of Arrival: 2017 Nov21 @ 12:00
Organism Lot #: AB171121 CT
Age upon Arrival: Second instar
Water (L) per Shipping Bag: ~1L
Organism: Chironomid dilutus
Number of Shipping Bags: 5
#of Organisms Ordered: 715
Light Intensity (lux): 664-737

Arrival Conditions

Bag ID	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	Analyst
1			465	20.5	16.0	6.8	n/a	mo
2			467	20.2	24.6	6.8	n/a	mo
3			467	20.5	20.8	6.7	n/a	mo
4			467	20.4	19.2	6.8	n/a	mo
5			469	20.3	16.1	6.7	n/a	mo

DML 2017 Dec20

Daily Conditions During Holding/Acclimation

Date	Mortalities		Water Quality					Analyst
	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	
Total Mortalities								

mo 2017 Nov21

Equipment ID: BBY2-0368

Comments (e.g. feeding times and quantities; fish behaviour, acclimation conditions): Analyst

2017 Nov 21 - Did WQ in all containers, aerated using spiderlines. mo

s.19(1)

ABI71121CT
OMC 2017 N0021

1300 Blue Spruce Drive, Suite C
Fort Collins, Colorado 80524

AQUATIC BIO SYSTEMS INC. ABS

Toll Free: 800/331-5916
Tel:970/484-5091 Fax:970/484-2514

ORGANISM HISTORY

DATE: 11/20/2017

SPECIES: *Chironomus dilutus (formerly C. tentans)*

AGE: Deposited 11/11/2017

LIFE STAGE: Second Instar 11/22/2017

HATCH DATE: Emergent date 12/5/2017

BEGAN FEEDING: Immediately

FOOD: *Raphidocelis subcapitata*.*, Flake slurry

Water Chemistry Record:	Current	Range
TEMPERATURE:	23°C	23-26°C
SALINITY/CONDUCTIVITY:	--	--
TOTAL HARDNESS (as $CaCO_3$):	152 mg/l	96-184 mg/l
TOTAL ALKALINITY (as $CaCO_3$):	100 mg/l	65-100 mg/l
pH:	7.94	7.83-8.20

Comments: * Formerly known as *Psuedokirschneriella subcapitata* and *Selenastrum capricornutum*

Facility Supervisor

Test: Chironomid dilutus   Start Date: 2017 Nov 21

Client # & Name: 99001 Hatfield Consultants

Back Wall		Position Map	
6	12	18	
5	11	17	
4	10	16	
3	9	15	
2	8	14	
1	7	13	etc.

Front of Counter

Position #	Sample ID	Replicate	Colour
16	Negative Control	A	Red
18		B	
12		C	
10		D	
1		E	
14		Measure	
15	JCL-1	A	Pink
2		B	
11		C	
3		D	
7		E	
8		Measure	
5	JCL-2	A	Purple
13		B	
9		C	
17		D	
4		E	
6		Measure	

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B7A3500
Report Date: 2017/11/28

Maxxam Analytics (TOX Internal)
Client Project #: Day 0 Overly 99001
Sampler Initials: MA

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		SN3364	SN3365	SN3366	
Sampling Date		2017/11/21	2017/11/21	2017/11/21	
COC Number		3688	3688	3688	
	UNITS	Control Day 0 Overly	JCL-1 Day 0 Overly	JCL-2 Day 0 Overly	RDL
Misc. Inorganics					
Alkalinity (Total as CaCO3)	mg/L	58.3	82.8	77.8	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	71.2	101	95.0	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	1.0
Nutrients					
Total Ammonia (N)	mg/L	0.038	0.74	0.058	0.020

RDL = Reportable Detection Limit

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B7A6793
Report Date: 2017/12/06

Maxxam Analytics (TOX Internal)
Client Project #: Day 10 Overly 99001
Sampler Initials: NB

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		SP1425		SP1426	SP1427	
Sampling Date		2017/12/01 08:50		2017/12/01 08:50	2017/12/01 08:50	
COC Number		3803		3803	3803	
	UNITS	Control Day 10 Overly	RDL	JCL-1 Day 10 Overly	JCL-2 Day 10 Overly	RDL
Misc. Inorganics						
Alkalinity (Total as CaCO3)	mg/L	93.4	1.0	82.3	102	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	114	1.0	100	124	1.0
Carbonate (CO3)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Nutrients						
Total Ammonia (N)	mg/L	4.1 (1)	0.20	0.84	0.20	0.020

RDL = Reportable Detection Limit

(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

APPENDIX

C 14-DAY *HYALELLA AZTECA* GROWTH AND SURVIVAL TEST

Hyalella 14-d Survival and Growth Sediment Test — Maxxam

Analysis ID:	12-5165-4134	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.9.2
Analyzed:	20 Dec-17 16:40	**Analysis:**	STP 2xK Contingency Tables	**Official Results:**	Yes
Batch ID:	04-2663-3511	**Test Type:**	Survival-Growth	**Analyst:**	
Start Date:	23 Nov-17 14:11	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Reconstituted Water
Ending Date:	07 Dec-17	**Species:**	Hyalella azteca	**Brine:**	Not Applicable
Duration:	13d 10h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Fisher Exact/Bonferroni-Holm Test

Sample I	vs	Sample II	Test Stat	P-Type	P-Value	Decision(α:5%)
Control		JCL-1	1.0000	Exact	1.0000	Non-Significant Effect
		JCL-2	0.1343	Exact	0.1343	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.117	2.548	0.3274	No Outliers Detected

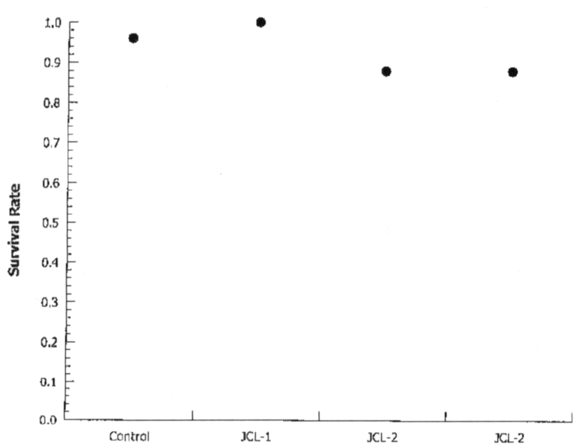
Data Summary

Group	Code	NR	R	NR + R	Prop NR	Prop R	%Effect
Control		48	2	50	0.96	0.04	0.0%
JCL-1		50	0	50	1	0	-4.17%
JCL-2		44	6	50	0.88	0.12	8.33%

Survival Rate Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control		1.0000	1.0000	1.0000	1.0000	0.8000
JCL-1		1.0000	1.0000	1.0000	1.0000	1.0000
JCL-2		0.8000	0.8000	0.8000	1.0000	1.0000

Graphics



Analyst: 2017 Dec 20 [signature] QA: NB 2017 Dec 21

CETIS Analytical Report

Report Date: 20 Dec-17 16:40 (p 1 of 2)
Test Code: HA-99001-0117 | 01-8932-7554

Hyalella 14-d Survival and Growth Sediment Test — Maxxam

Analysis ID:	14-6472-1445	**Endpoint:**	Mean Dry Weight-mg	**CETIS Version:**	CETISv1.9.2
Analyzed:	20 Dec-17 16:40	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes

Batch ID:	04-2663-3511	**Test Type:**	Survival-Growth	**Analyst:**	
Start Date:	23 Nov-17 14:11	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Reconstituted Water
Ending Date:	07 Dec-17	**Species:**	Hyalella azteca	**Brine:**	Not Applicable
Duration:	13d 10h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Data Transform	Alt Hyp	Comparison Result	PMSD
Untransformed	C > T	JCL-1 passed mean dry weight-mg	12.94%
		JCL-2 failed mean dry weight-mg	12.94%

Dunnett Multiple Comparison Test

Sample I	vs	Sample II	Test Stat	Critical	MSD	DF	P-Type	P-Value	Decision(α:5%)
Control		JCL-1	-2.095	2.108	0.017	8	CDF	0.9931	Non-Significant Effect
		JCL-2*	5.682	2.108	0.017	8	CDF	9.8E-05	Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.328	2.548	0.1435	No Outliers Detected

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.0106597	0.0053299	2	32.39	1.5E-05	Significant Effect
Error	0.0019749	0.0001646	12			
Total	0.0126346		14			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance Test	2.159	9.21	0.3398	Equal Variances
Distribution	Shapiro-Wilk W Normality Test	0.9199	0.8328	0.1921	Normal Distribution

Mean Dry Weight-mg Summary

Group	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
Control		5	0.1322	0.1231	0.1413	0.134	0.122	0.142	0.003292	5.57%	0.00%
JCL-1		5	0.1492	0.1333	0.1651	0.15	0.135	0.168	0.005722	8.58%	-12.86%
JCL-2		5	0.0861	0.06548	0.1067	0.0825	0.071	0.1138	0.007427	19.29%	34.87%

Mean Dry Weight-mg Detail

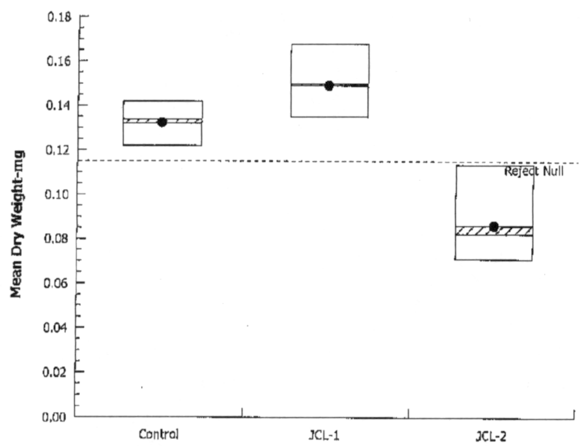
Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control		0.134	0.129	0.122	0.134	0.142
JCL-1		0.135	0.168	0.14	0.153	0.15
JCL-2		0.1138	0.07625	0.0825	0.087	0.071

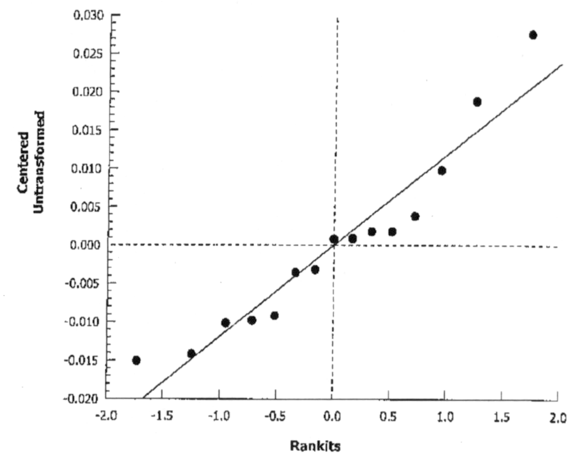
Analyst: 2017 Dec 20 DMC QA: NB 2017 Dec 21

Hyalella 14-d Survival and Growth Sediment Test | **Maxxam**

Analysis ID:	14-6472-1445	Endpoint:	Mean Dry Weight-mg	CETIS Version:	CETISv1.9.2
Analyzed:	20 Dec-17 16:40	Analysis:	Parametric-Control vs Treatments	Official Results:	Yes

Graphics





Analyst: 2017 Dec20 [signature] QA: 2017 Dec21 MB

ECOTOXICOLOGY

Hyalella azteca Survival and Growth Test - Survival

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00275/4

Client # & Name: 99001 - Hatfield

Job # B794914

Organism Lot #: AB171121

Analysts: N. Blassnitz, M O'toole

Start Date and Time: 2017 Nov 23 @ 14:11

End Date: 2017 Dec 07

Sample	Rep	Initial # Hyalella	Final # Hyalella	% Survived	Survival	
					Mean %	SD %
Control	A	10	10	100	96	9
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	8	80		
JCL-1	A	10	10	100	100	0
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		
JCL-2	A	10	8	80	88	11
	B	10	8	80		
	C	10	8	80		
	D	10	10	100		
	E	10	10	100		

Proofed: NB 2017 Dec21

Hyalella azteca Survival and Growth Test - Dry Weights

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00129/4

Client # & Name: 99001-Hatfeild Consultants
Start Date and Time: 2017 Nov 23@14:11
Job/Sample #: B794914
End Date: 2017 Dec 07
Organism Lot #: AB171121
Drying Temperature (°C): 60
Weighing Dates: 2017 Dec 18
Drying Time (h): >24
Analysts: D. Lai

Boat #	Sample	Rep	# *Hyalella*	*Hyalella* Wt.(g)	*Hyalella* Wt. (mg)	Mean Wt./*Hyalella* (mg)	Mean Wt./Sample (mg)	SD
16	Control	A	10	0.00134	1.34	0.13	0.13	0.01
17		B	10	0.00129	1.29	0.13		
18		C	10	0.00122	1.22	0.12		
19		D	10	0.00134	1.34	0.13		
20		E	10	0.00142	1.42	0.14		
21	JCL-1	A	10	0.00135	1.35	0.14	0.15	0.01
22		B	10	0.00168	1.68	0.17		
23		C	10	0.00140	1.40	0.14		
24		D	10	0.00153	1.53	0.15		
25		E	10	0.00150	1.50	0.15		
26	JCL-2	A	8	0.00091	0.91	0.11	0.09	0.02
27		B	8	0.00061	0.61	0.08		
28		C	8	0.00066	0.66	0.08		
29		D	10	0.00087	0.87	0.09		
30		E	10	0.00071	0.71	0.07		
17		QA/QC	10	0.00134	1.34	0.13	-	-
28		QA/QC	8	0.00064	0.64	0.08	-	-
16		0 - A	10	0.00133	1.33	0.13	-	-
		Analyst:		DML				

The average dry weight for the replicate controls must be ≥0.1 mg, for the test to be valid.

Notes:

Sample ID: Control
Job #: n/a
Start Date: November 23, 2017
End Date: December 7, 2017

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.2	8.3	128	136	425	548	52.3	85.6	0.16	4.1

Initial overlying WQ measurements:	
Analyst T. Wollelo	Date 2017 nov 23

Final overlying WQ measurements:	
Analyst NB	Date 2017 Dec 07

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Thursday Day 14
Temp. (ºC)	23.2	24.3	24.1	23.0	23.V	23.1	22.1
D.O. (mg/L)	8.4	8.1	8.1	8.5	8.4	8.6	8.7
Subsampled for ammonia (√)	✓						✓
Feeding	✓	✓	✓	✓	✓	✓	
Analyst	TW	[initials]	[initials]	SR	[initials]	DML	NB

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	8
Analyst	NB	NB	NB	NB	mo

Date	Replicate	Comments	Analyst
2017 NOV 23	Measure	Did WQ on measure	[initials]
2017 NOV 28	Measure	Did WQ on measure	[initials]
2017 DEC 02	Measure	Did WQ on measure	[initials]

DML 2017 DEC 20

Maxxam
A Bureau Veritas Group Company

ECOTOXICOLOGY

BBY2FCD-00143/5

HYALELLA AZTECA SURVIVAL AND GROWTH TEST - DATA SHEET

Page 1: **Sample**

Sample ID: JCL-1

Start Date: November 23, 2017

Job #/Sample #: B794914/SI0808

End Date: December 7, 2017

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.2	8.2	148	168	422	474	73.9	87.0	0.18	0.050

Initial overlying WQ measurements:	
Analyst T. Wollelo	Date 2017nov23

Final overlying WQ measurements:	
Analyst NB	Date 2017Dec07

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Thursday Day 14
Temp. (ºC)	23.5	24.3	24.1	23.3	23.4	22.9	22.0
D.O. (mg/L)	8.3	8.0	8.1	8.5	8.3	8.7	8.6
Subsampled for ammonia (√)	✓						✓
Feeding	✓	✓	✓	✓	✓	✓	
Analyst	T.W	J	J	SR	J	DML	NB

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	10
Analyst	mo	mo	mo	mo	mo

Date	Replicate	Comments	Analyst
2017Nov25	Measure	Did WQ on measure	J
2017Nov28	Measure	Did WQ on measure	J
2017Dec01	Measure	Did WQ on measure	J

DML 2017Dec20

ECOTOXICOLOGY

HYALELLA AZTECA SURVIVAL AND GROWTH TEST - DATA SHEET

Sample ID: JCL-2
Start Date: November 23, 2017
Job #/Sample #: B794914/SI0809
End Date: December 7, 2017

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (mg/L $CaCO_3$)		Ammonia (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.2	8.2	148	180	424	503	67.8	91.6	0.41	0.066

Initial overlying WQ measurements:	
Analyst T. Wollelo	Date 2017 nov 23

Final overlying WQ measurements:	
Analyst NB	Date 2017 Dec 07

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Thursday Day 14
Temp. (ºC)	23.6	24.4	24.2	23.4	23.4	22.8	21.9
D.O. (mg/L)	8.2	8.1	8.1	8.4	8.3	8.7	8.6
Subsampled for ammonia (√)	✓						✓
Feeding	✓	✓	✓	✓	✓	✓	
Analyst	TW	Y	Y	SR	Y	DMC	NB

Replicate	A	B	C	D	E
# Surviving	8	8	8	10	10
Analyst	mo	mo	mo	mo	mo

Date	Replicate	Comments	Analyst
2017 Nov 25	Measure	Did WQ on measure	Y
2017 Nov 28	Measure	Did WQ on measure	Y
2017 Dec 02	Measure	Did WQ on measure	Y

DMC 2017 Dec 20

Client # & Name: 99001 Hatfield Consultants

Job #: B794914

Test Initiation Date & Time: 2017 Nov 23 @ 14:11

Test Completion Date: 2017 Dec 07

Room #: 105

Analyst(s): T. Wollelo, [illegible], N. Acessnitz, D. Lai, M. O'Toole, S. Rostanda

Control Water Batch: 2017 NOV 17

Control Sediment: Yaquina Bay beach sand

Organism Lot: AB171121HA

Age at Start of Test: 7-9 days

Feeding Regime: 1.75mL YCT & 800µL tetramin slurry (4g/L) per replicate 3x weekly

YCT Batch Number: 2017 NOV 14, 2017 Nov09

Tetramin Preparation Date: 2017 NOV 03, 2017 Nov27

Balance ID: ~~BBY2-0368~~ BBY2-0260

Drying Oven ID: BBY2-0278

WQ Instrument ID: BBY2-0368

Additional Comments: DNL 2017 Dec20

ECOTOXICOLOGY

***HYALELLA AZTECA* SURVIVAL AND GROWTH TEST – AERATION CHECKS**

Client # & Name: 99001, Hatfield Consultants Start Date: 2017 Nov 23

Initial when aeration is checked. If air is off record DO and note which replicate(s) in comments section.

	Day -1	Day 0	1	2	3	4	5	6
Date	2017 Nov22	2017 Nov23	2017 Nov24	2017 Nov25	2017 Nov26	2017 Nov 27	2017 Nov28	2017 Nov29
Early AM	n/a	TW	TW	[initials]	NS	TW	[initials]	[initials]
Mid-day	mo	TW	TW	[initials]	NS	TW	[initials]	[initials]
Late PM	mo	SR	[initials]	[initials]	NS	mo	SR	[initials]

	Day 7	8	9	10	11	12	13	14
Date	2017 Nov30	2017 Ⓐ Dec01	2017 Dec02	2017 Dec03	2017 Dec04	2017 Dec05	2017 Dec06	2017 Dec07
Early AM	[initials]	NB	NB	NB	mo	NS	NS	NB
Mid-day	SR	SR	[initials]	NB	mo	Dmc	[initials]	
Late PM	[initials]	SR	NB	NB	mo	Dmc	[initials]	Dmc 2017 Dec20

Comments:

Aeration started at 14:18 - mo 2017 Nov 22

Ⓐ WE NB 2017 Dec01

Dmc 2017 Dec20

ORGANISMS - ACCLIMATION AND HOLDING CONDITIONS

Client #'s : 10025, 99001

Date & Time of Arrival: 2017Nov21@12:00

Organism Lot #: AB171121 HA

Age upon Arrival: 5-7days

Water (L) per Shipping Bag: ~1L

Organism: Hyalella azteca

Number of Shipping Bags: 1

#of Organisms Ordered: 580

Light Intensity (lux): 664-737

Arrival Conditions

Bag ID	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	Analyst
1	0	0	807	20.6	8.1	7.4	✓	mo

DMC 2017Dec20

Daily Conditions During Holding/Acclimation

Date	Mortalities		Water Quality					Analyst
	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	
2017Nov22	0	0	692	22.8	8.3	8.0	✓	mo
2017nov23	0	0	561	23.1	8.3	8.0	N/A	TW
Total Mortalities	0	0						

DMC 2017 Dec20

Equipment ID: BBY2-0368

Comments (e.g. feeding times and quantities; fish behaviour, acclimation conditions): Analyst

2017Nov21 - Poured container into pyrex dish. Started aeration with spider lines. Fed 5mL of YCT batch 2017Nov14, and 5mL tetramin slurry batch 2017Nov03. Topped up dish with Hyalella H_2O 2017Nov17 - mo

2017Nov22 - Did WQ + 50% H_2O Δ on pyrex dish, fed 5mL YCT batch 2017Nov14 and 5mL tetramin slurry batch 2017Nov03. - mo

1300 Blue Spruce Drive, Suite C
Fort Collins, Colorado 80524

AQUATIC BIO SYSTEMS ABS INC.

Toll Free: 800/331-5916
Tel: 970/484-5091 Fax:970/484-2514

ORGANISM HISTORY

DATE: 11/20/2017

SPECIES: *Hyalella azteca*

AGE: 4-6 day

LIFE STAGE: Juvenile

HATCH DATE: Variable

BEGAN FEEDING: Immediately

FOOD: Flake slurry

Water Chemistry Record:	Current	Range
TEMPERATURE:	23°C	23-26°C
SALINITY/CONDUCTIVITY:	--	--
TOTAL HARDNESS (as $CaCO_3$):	138 mg/l	96-184 mg/l
TOTAL ALKALINITY (as $CaCO_3$):	70 mg/l	50-80 mg/l
pH:	7.49	7.20-8.16

Comments:

Facility Supervisor

SAM-5S Water Recipe for Hyalella

BATCH ID: 2017 Nov17
(Date Hardened)

SAM-5S Reconstituted Water Recipe for *Hyalella azteca*
as per Borgmann 1996 (For water hardness ~125 mg/L)

Chemical Weights	$CaCl_2X2H_2O$	$MgSO_4$ (g)	NaBr (g)	$NaHCO_3$ (g)	KCl (g)
Brand	Fisher	Fisher	Acros	Fisher	Fishe
Lot #	171431	166168	A0378421	165272	149363
Calculated	7.35	1.50	0.05	4.20	0.19
Actual	7.3503	1.5006	0.0500	4.2004	0.1896

Balance ID: BBY2-0421

Analyst: NBlassnitz

Add to Type 3 DI (L): 50

Water Use: 10025t99001

DI Machine ID: BBY2-0158 / BBY2-0160

Date: 2017 Nov17

Water Quality:

Temp (°C): 22.7 pH: 8.1 Hardness (mg/L) 132

Cond (µs/cm): 423 DO (mg/L): 8.5 Alkalinity (mg/L): n/a

Analyst: M.O'Tode Date: 2017Nov21

Comments:

NaHCO3 (Sodium Bicarbonate)

NaBr (Sodium Bromide)

CaCl2 x 2H2O (Calcium Chloride - dihydrous)

MgSO4 (Magnesium Sulfate - anhydrous)

KCl (Potassium Chloride)

SAM-5S Recipe = 1 mM CaCl2, 1 mM NaHCO3, 0.01 mM NaBr, 0.05 mM KCl, and 0.25 mM MgSO4

Borgmann, U. 1996. Systematic analysis of aqueous ion requirements of *Hyalella azteca* : A standard artificial medium including the essential bromide ion. *Archives of Environmental Contamination and Toxicology* . 30: 356-363.

Randomization Chart
Tab: Sediment Tests

Test: Hyalella azteca   Start Date: 2017 Nov 23

Client # & Name: 99001 Hatfield Consultants

Back Wall		Position Map	
6	12	18	
5	11	17	
4	10	16	
3	9	15	
2	8	14	
1	7	13	etc.

Front of Counter

Position #	Sample ID	Replicate	Colour
1	Negative Control	A	Red
4		B	
12		C	
9		D	
5		E	
11		Measure	
6	JCL-1	A	Pink
7		B	
15		C	
18		D	
16		E	
3		Measure	
14	JCL-2	A	Purple
13		B	
10		C	
17		D	
2		E	
8		Measure	

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B7A4293
Report Date: 2017/11/29

Maxxam Analytics (TOX Internal)
Client Project #: Hyallela Overlying Day 0 99001
Sampler Initials: TW

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		SN7059	SN7060	SN7061	
Sampling Date		2017/11/23 10:15	2017/11/23 10:15	2017/11/23 10:15	
COC Number		3710	3710	3710	
	UNITS	**99001 Cntrl Hyalella Overly Day 0**	**99001 JCL-1 Hyalella Overly Day 0**	**99001 JCL-2 Hyalella Overly Day 0**	**RDL**
Misc. Inorganics					
Alkalinity (Total as CaCO3)	mg/L	52.3	73.9	67.8	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	63.8	90.1	82.7	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	1.0
Nutrients					
Total Ammonia (N)	mg/L	0.16	0.18	0.41	0.020

RDL = Reportable Detection Limit

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam
A Bureau Veritas Group Company

Maxxam Job #: B7A8695
Report Date: 2017/12/12

Maxxam Analytics (TOX Internal)
Client Project #: Hyallela Overlying Day 1 99001
Sampler Initials: NB

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		SQ1992		SQ1993	SQ1994	
Sampling Date		2017/12/07 09:06		2017/12/07 09:06	2017/12/07 09:06	
COC Number		3879		3879	3879	
	UNITS	Control Overly Day 14 Hy	RDL	JCL-1 Overly Day 14 Hy	JCL-2 Overly Day 14 Hy	RDL
Misc. Inorganics						
Alkalinity (Total as CaCO3)	mg/L	85.6	1.0	87.0	91.6	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	104	1.0	106	112	1.0
Carbonate (CO3)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	1.0	<1.0	<1.0	1.0
Nutrients						
Total Ammonia (N)	mg/L	4.1 (1)	0.10	0.050	0.066	0.020

RDL = Reportable Detection Limit

(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Appendix A3

Fish Capture Data and Fishing Effort

Table A3.1 Fish Capture Locations, Jackpine Lake, 2017.

Site	Pass/Set number	UTM E Start	UTM N Start	UTM E End	UTM N End	Start Date	Start Time	End Time	Effort (sec)	Effort (hrs)	Number fish captured
EF	JCL-12	475671	6350308	475763	6350378	18-Oct-17	10:20	10:30	111		0
EF	JCL-11	475790	6350288	475898	6350261	18-Oct-17	10:30	10:36	103		2
EF	JCL-9 (1)	475831	6350408	475893	6350516	18-Oct-17	10:40	10:50	110		0
EF	JCL-9 (2)	475938	6350586	476011	6350668	18-Oct-17	10:56	11:03	147		3
EF	JCL-7	476091	6350754	476195	6350754	18-Oct-17	12:30	12:40	141		1
EF	JCL-6	476409	6351174	476477	6351277	18-Oct-17	13:00	13:06	207		0
EF	JCL-5	476485	6351410	476454	6351524	18-Oct-17	13:10	13:13	123		0
EF	JCL-3	476426	6351999	476506	6352083	18-Oct-17	13:19	13:23	124		1
EF	JCL-4	476506	6351775	476519	6351665	18-Oct-17	13:28	13:32	143		0
EF	JCL-8	476495	6351137	476501	6351018	18-Oct-17	13:39	13:44	158		1
EF	JCL-10	476418	6350469	476354	6350381	18-Oct-17	13:51	13:56	157		0
EF	P1	476354	6350381	475985	6350652	18-Oct-17	14:00	15:00	2067		13
AN	AN1	476341	6350402	*n/a*		19-Oct-17	9:15	9:30		0.25	0
AN	AN2	476435	6350469	*n/a*		19-Oct-17	9:40	9:55		0.25	0
AN	AN3	476083	6350276	*n/a*		19-Oct-17	10:03	10:18		0.25	2
AN	AN4	475888	6350281	*n/a*		19-Oct-17	10:28	10:43		0.25	2
AN	AN5	475783	6350307	*n/a*		19-Oct-17	10:49	11:04		0.25	2
AN	AN6	475707	6350345	*n/a*		19-Oct-17	12:23	12:45		0.37	6

Note: Angling was conducted as casting from a fixed location.

Table A3.2 Detailed Fish Sampling and Analysis, Jackpine Lake, 2017.

Year	Waterbody	Site	Date	Sampling Technique	Fish ID	Species Code	Length (mm)	Weight (g)	Stage Code	Maturity Code	Sex	Tag Type	Tag Number	Mercury Sample Collected (Y/N)	Cleithra Collected (Y/N)	Age (years)	Mercury Content (ng/g dry wt)	Mercury Content (ng/g wet weight)	Comments
2017	Jackpine Lake	JCL-11	18-Oct-17	EF	1	NRPK	165	31.12	U	U	U	PIT	9890010 06757835	Y	Y	0	200	33.8	
2017	Jackpine Lake	JCL-11	18-Oct-17	EF	2	NRPK	302	170.64	U	U	U	PIT	9890010 06757810	Y	Y	2	470	39.1	
2017	Jackpine Lake	JCL-9	18-Oct-17	EF	3	NRPK	536	1140	U	U	U	PIT	9890010 06757840	Y	Y	4	1490	198	
2017	Jackpine Lake	JCL-9	18-Oct-17	EF	4	NRPK	314	215.23	U	U	U	PIT	9890010 06757896	Y	Y	2	319	65.6	
2017	Jackpine Lake	JCL-9	18-Oct-17	EF	5	NRPK	280	146.37	U	U	U	PIT	9890010 06757811	Y	Y	2	234	41.6	
2017	Jackpine Lake	JCL-3	18-Oct-17	EF	6	NRPK	320	211.93	U	U	U	PIT	9890010 06757848	Y	Y	2	324	57.7	
2017	Jackpine Lake	JCL-7	18-Oct-17	EF	7	NRPK	269	125.01	U	U	U	PIT	9890010 06757892	Y	Y	2	759	132	
2017	Jackpine Lake	P1	18-Oct-17	EF	8	NRPK	388	340	U	U	U	PIT	9890010 06757852	Y	Y	2	481	76.7	
2017	Jackpine Lake	P1	18-Oct-17	EF	9	NRPK	330	230	U	U	U	PIT	9890010 06757805	Y	Y	2	229	37.3	
2017	Jackpine Lake	P1	18-Oct-17	EF	10	NRPK	337	230	U	U	U	PIT	9890010 06757816	Y	Y	3	605	109	
2017	Jackpine Lake	P1	18-Oct-17	EF	11	NRPK	322	220	U	U	U	PIT	9890010 06757869	Y	Y	3	484	80.7	
2017	Jackpine Lake	P1	18-Oct-17	EF	12	NRPK	273	142.61	U	U	U	PIT	9890010 06757874	Y	Y	3	200	35.1	
2017	Jackpine Lake	JCL-8	18-Oct-17	EF	13	NRPK	740	3210	U	U	U	PIT	9820001 80967331	Y	N	7	2980	381	Recapture
2017	Jackpine Lake	P1	18-Oct-17	EF	14	NRPK	722	2530	U	U	U	PIT	9890010 06757829	Y	Y	5	1540	284	
2017	Jackpine Lake	P1	18-Oct-17	EF	15	NRPK	588	1420	U	U	U	PIT	9890010 06757847	Y	Y	4	1700	263	
2017	Jackpine Lake	P1	18-Oct-17	EF	16	NRPK	651	2020	U	U	U	PIT	9890010 06757864	Y	Y	5	2910	306	
2017	Jackpine Lake	P1	18-Oct-17	EF	17	NRPK	549	1470	U	U	U	PIT	9890010 06757885	Y	Y	5	2050	360	
2017	Jackpine Lake	P1	18-Oct-17	EF	18	NRPK	568	1660	U	U	U	PIT	9890010 06757883	Y	Y	5	1200	209	
2017	Jackpine Lake	P1	18-Oct-17	EF	19	NRPK	308	191.65	U	U	U	PIT	9890010 06757870	Y	Y	2	412	74.7	
2017	Jackpine Lake	P1	18-Oct-17	EF	20	NRPK	435	610	U	U	U	PIT	9890010 06757842	Y	Y	4	295	59.4	
2017	Jackpine Lake	P1	19-Oct-17	EF	21	NRPK	315	218.75	U	U	U	PIT	9890010 06757815	Y	Y	2	455	72	
2017	Jackpine Lake	AN3	19-Oct-17	AN	22	NRPK	384	340	U	U	U	PIT	9890010 06757809	Y	Y	2	490	86.6	
2017	Jackpine Lake	AN3	19-Oct-17	AN	23	NRPK	547	1480	U	U	U	PIT	9820001 80967496	Y	N	5	1920	323	Recapture
2017	Jackpine Lake	AN4	19-Oct-17	AN	24	NRPK	690	2740	U	U	U	PIT	9890010 06757868	Y	Y	9	2630	496	
2017	Jackpine Lake	AN4	19-Oct-17	AN	25	NRPK	599	1750	U	U	U	PIT	9890010 06757826	Y	Y	5	2080	394	
2017	Jackpine Lake	AN5	19-Oct-17	AN	26	NRPK	582	1890	A	U	U	PIT	9890010 06757806	Y	Y	4	2050	313	
2017	Jackpine Lake	AN5	19-Oct-17	AN	27	NRPK	572	1670	A	U	U	PIT	9890010 06757817	Y	Y	3	1700	284	
2017	Jackpine Lake	AN6	19-Oct-17	AN	28	NRPK	491	880	A	U	U	PIT	9890010 06757895	Y	Y	3	1320	246	
2017	Jackpine Lake	AN6	19-Oct-17	AN	29	NRPK	519	980	A	U	U	PIT	9890010 06757837	Y	Y	4	2480	435	
2017	Jackpine Lake	AN6	19-Oct-17	AN	30	NRPK	531	1000	A	U	U	PIT	9890010 06757839	Y	Y	4	2120	378	
2017	Jackpine Lake	AN6	19-Oct-17	AN	31	NRPK	491	1140	A	U	U	FLOY	SUSFE 0896	N	N	U			
2017	Jackpine Lake	AN6	19-Oct-17	AN	32	NRPK	570	1570	A	U	U	PIT	9890010 06757812	N	Y	5			
2017	Jackpine Lake	AN6	19-Oct-17	AN	33	NRPK	526	1300	A	U	U	PIT	9890010 06757851	N	Y	3			

Note: Northern pike tissue mercury was measured as total methyl-mercury in 2017.

Appendix A4

Fish Ageing and Mercury Concentrations

2017/2018

Company Name: Hatfield
Project Name: Jackpine Lake SHELL 8642
Client Contact: Ben Beall Kaitlyn Roberts
Phone #:
Email:
& Type of Structures: 30 FR
Work to be Completed:
Invoice:

Location	Date	Structures	Species	Sample/Fish #	Age KA	Con. Index	QA/QC MB	Comments
JCL-11	18-Oct-17	FR	NRPK	1	0	F		
JCL-11	18-Oct-17	FR	NRPK	2	2	F		
JCL-9	18-Oct-17	FR	NRPK	3	4	F		
JCL-9	18-Oct-17	FR	NRPK	4	2	F		
JCL-9	18-Oct-17	FR	NRPK	5	2	F		
JCL-3	18-Oct-17	FR	NRPK	6	2	F		
JCL-7	18-Oct-17	FR	NRPK	7	2	F		
P1	18-Oct-17	FR	NRPK	8	2	F		
P1	18-Oct-17	FR	NRPK	9	2	F		
P1	18-Oct-17	FR	NRPK	10	3	F		
P1	18-Oct-17	FR	NRPK	11	3	F		
P1	18-Oct-17	FR	NRPK	12	3	F		
P1	18-Oct-17	FR	NRPK	14	5	G		
P1	18-Oct-17	FR	NRPK	15	4	F		
P1	18-Oct-17	FR	NRPK	16	5	F		
P1	18-Oct-17	FR	NRPK	17	5	G		
P1	18-Oct-17	FR	NRPK	18	5	G	5	
P1	18-Oct-17	FR	NRPK	19	2	F	2	
P1	18-Oct-17	FR	NRPK	20	4	G	4	
P1	18-Oct-17	FR	NRPK	21	2	F		
AN3	19-Oct-17	FR	NRPK	22	2	F		
AN4	19-Oct-17	FR	NRPK	24	5	F		
AN4	19-Oct-17	FR	NRPK	25	5	F		
AN5	19-Oct-17	FR	NRPK	26	4	G		
AN5	19-Oct-17	FR	NRPK	27	3	F		
AN6	19-Oct-17	FR	NRPK	28	3	G		
AN6	19-Oct-17	FR	NRPK	29	4	F		
AN6	19-Oct-17	FR	NRPK	30	4	F		
AN6	19-Oct-17	FR	NRPK	32	5	G		
AN6	19-Oct-17	FR	NRPK	33	3	G		

Methyl Mercury Results

Flett Research Ltd.
440 DeSalaberry Ave. Winnipeg, MB R2L 0Y7
Fax/Phone (204) 667-2505
E-mail: flett@flettresearch.ca Webpage: http://www.flettresearch.ca

CLIENT: Hatfield Consultants - SHELL: 8642 CNRL Jackpine Lake
200 - 850 Harbourside Dr.
North Vancouver, BC V7P 0A3

Matrix: Tissue(dry)
Transaction ID: 837
PO/Contract No.:
Date Received: October 25, 2017
Sampling Date: October 18, 2017
Date Analysed: November 22, 2017
Analyst(s): Xiang W.

Analytical Method: M10220: Methyl Mercury in Tissue by Digestion, Aqueous Ethylation, Purge & Trap, and CVAFS with an Automated System (Version 3)
P:\Methyl Mercury\Method and SOPs\M10220 MeHg in Tissue by Digestion - Automated System.doc

Comments: Dermal plug samples were freeze dried at Flett Research prior to analysis to eliminate errors associated with loss of moisture which can occur in small tissue samples. When present the dark portion of scale and skin from the tip of the dermal plug is removed prior to mercury analysis.

**Based on our experience percent loss on drying results normally fall between 78% and 82% in fish muscle tissue. %LOD results which fall outside of this range are considered aberrant. A high %LOD result may be due to inclusion of water droplets during tissue sampling in the field while a low %LOD result may be the result of compression of the tissue during the sampling procedure which results in a loss of moisture from the tissue.

Irregular %LOD results have been replaced with a value of 80% which is considered typical for %LOD of muscle tissue in fish. These corrections affect the wet weight concentrations of total Hg; there is no affect upon the dry weight total Hg concentrations. Original %LOD values can be found on the wet_wt-dry_wt sheet in this workbook.

Detection Limit: 16 ng/g (ML) MDL=4 ng/g The MDL was determined based on 7 replicates of analytical blanks (98% confidence level) and a 20 mg dry sample size.

For reporting purposes results will be flagged below the ML which is considered a practical quantitation limit.

Estimated Uncertainty: The estimated uncertainty of this method has been determined to be ± 13%

Results authorized by Dr. Robert J. Flett, Chief Scientist

QUALITY DATA

Blanks		pg of MeHg in whole ethylation EPA vial	Gross Peak Area	Mean Ethylation Blank (ng/L)					
	Ethylation blank ($H_2$0+Reagent)	0.35	979	0.01					
	Mean Eth. Blank (last 30 runs)	0.33		0.01					
		Net pg MeHg in whole Ethylation EPA vial	Gross Peak Area	Equiv. CH Hg Conc. - based on current batch mean weight (0.0037g) of dry sample, ng/g (Biota)					
	Method Blank 1	0.25	1677	5.553					
	Method Blank 2	0.13	1348	2.972					
	Method Blank 3	0.05	1125	1.111					
	Mean Method Blank	0.15		3.212					
Standards		MeHg Standard Added to Ethylation EPA Vial (pg CH_3Hg)	Gross Peak Area	Net Corrected MeHg Std Calibration Factor (units / pg)	RSD of MeHg Standard				
	Mean Value			4707	2.8				
Spike Recovery Matrix Spike (MS) and Matrix Spike Duplicate (MSD)	Sample Identification	Sample Type	Gross Peak Area	% CH_3Hg Recovery Used for Calculations	Dry Sample Mass (g)	% Wt. Loss On Drying	Net CH_3Hg as Hg (ng/g-Dry-Wt)	Net CH_3Hg as Hg (ng/g-Wet-Wt)	CH_3Hg Recovery (%)
	JCL-9-05-NRPK (FID 5)	MS1	423731	100%	0.004	83.2	2855	508	95.1
	JCL-9-05-NRPK (FID 5)	MS1D	406146	100%	0.003	83.2	4349	773	95.6
	P1-11-NRPK (FID 11)	MS2	371823	100%	0.002	83.3	4837	806	83.2
	P1-15-NRPK (FID 15)	MS3	497734	100%	0.003	84.6	5097	787	85.5
	Mean of Recoveries								**89.9**
QC Samples	Dorm-4 ID1501 (355± 28 ng/g)		446005	100%	0.038	3.3			99.5
	Dorm-4 ID1501 (355± 28 ng/g)	**Repeat Aliquot**	450138	100%	0.038	3.3			100.4
	Mean of Dorm-4						355		**99.9**
Alternate Source Standard (A.S.S.)	A.S.S. - Alfa ID1302 (1000 ng/L)		164829	100%			986	<- Net CH_3Hg as Hg (ng/L)	**98.6**

LAB ID	Sampling Details	Sample ID	Date Sampled	Sample Type	Gross Peak Area	% CH_3Hg Recovery Used for Calculations	Weighed Dry Sample Mass (g)	**% Wt. Loss On Drying	Net CH3Hg as Hg (ng/g) Dry Wt. [recovery corrected] As Analyzed	Net CH3Hg as Hg (ng/g) Wet Wt. [recovery corrected] As Calculated
85194	JCL-11-01-NRPK	FID 1	October 18, 2017		35035	89.9	0.0056	80	**200**	**33.8**
85195	JCL-11-02-NRPK	FID 2	October 18, 2017		51554	89.9	0.0036	80	**470**	**39.1**
85196	JCL-9-03-NRPK	FID 3	October 18, 2017		171491	89.9	0.0039	80	**1490**	**198**
85197	JCL-9-04-NRPK	FID 4	October 18, 2017		51510	89.9	0.0053	79.4	**319**	**65.6**
85198	JCL-9-05-NRPK	FID 5	October 18, 2017		20672	89.9	0.0028	82.2	**234**	**41.6**
85199	JCL-3-06-NRPK	FID 6	October 18, 2017		25161	89.9	0.0025	82.2	**324**	**57.7**
85200	JCL-7-07-NRPK	FID 7	October 18, 2017		101577	89.9	0.0045	80	**759**	**132**
85201	P1-08-NRPK	FID 8	October 18, 2017		38844	89.9	0.0026	80	**481**	**76.7**
85202	P1-09-NRPK	FID 9	October 18, 2017		19259	89.9	0.0026	80	**229**	**37.3**
85203	P1-10-NRPK	FID 10	October 18, 2017	DupA1	65968	89.9	0.0036	82.0	**605**	**109**
85203	P1-10-NRPK	FID 10	October 18, 2017	DupA2	53037	89.9	0.0029	82.0	**609**	**110**
85204	P1-11-NRPK	FID 11	October 18, 2017		43086	89.9	0.0029	80	**484**	**80.7**
85205	P1-12-NRPK	FID 12	October 18, 2017		15979	89.9	0.0025	82.4	**200**	**35.1**
85206	JCL-8-13-NRPK	FID 13	October 18, 2017		233079	89.9	0.0026	80	**2980**	**381**
85207	P1-14-NRPK	FID 14	October 18, 2017		243293	89.9	0.0053	81.5	**1540**	**284**
85208	P1-15-NRPK	FID 15	October 18, 2017		181096	89.9	0.0036	80	**1700**	**263**
85209	P1-16-NRPK	FID 16	October 18, 2017		273721	89.9	0.0032	80	**2910**	**306**
85210	P1-17-NRPK	FID 17	October 18, 2017		322222	89.9	0.0053	80	**2050**	**360**
85211	P1-18-NRPK	FID 18	October 18, 2017		128772	89.9	0.0036	80	**1200**	**209**
85212	P1-19-NRPK	FID 19	October 18, 2017		56866	89.9	0.0046	81.8	**412**	**74.7**
85213	P1-20-NRPK	FID 20	October 18, 2017	DupB1	40519	89.9	0.0045	79.8	**295**	**59.4**
85213	P1-20-NRPK	FID 20	October 18, 2017	DupB2	40404	89.9	0.0045	79.8	**292**	**58.8**

* : See 'Comments' section above for discussion.

Q:\Clients A-L\Hatfield Consultants - SHELL\2017(837)\Methyl Hg\MTBIOT112217XW1.xls

Dup : Duplicate - two subsamples of the same sample carried through the analytical procedure in an identical manner.

ilac-MRA CALA Testing Accreditation No. A 3306

ISO/IEC17025:2005 Accredited with the Canadian Association for Laboratory Accreditation

Methyl Mercury Results

Flett Research Ltd.
440 DeSalaberry Ave. Winnipeg, MB R2L 0Y7
Fax/Phone (204) 667-2505
E-mail: flett@flettresearch.ca Webpage: http://www.flettresearch.ca

CLIENT: Hatfield Consultants - SHELL: 8642 CNRL Jackpine Lake
200 - 850 Harbourside Dr.
North Vancouver, BC V7P 0A3

Date Received: October 25, 2017
Sampling Date: October 18, 2017 to October 19, 2017

Matrix: Tissue(dry)
Transaction ID: 837
PO/Contract No.:
Date Analysed: November 24, 2017
Analyst(s): Xiang W.

Analytical Method: M10220: Methyl Mercury in Tissue by Digestion, Aqueous Ethylation, Purge & Trap, and CVAFS with an Automated System (Version 3)
P:\Methyl Mercury\Method and SOPs\M10220 MeHg in Tissue by Digestion - Automated System.doc

Comments: Dermal plug samples were freeze dried at Flett Research prior to analysis to eliminate errors associated with loss of moisture which can occur in small tissue samples. When present the dark portion of scale and skin from the tip of the dermal plug is removed prior to mercury analysis.

**Based on our experience percent loss on drying results normally fall between 78% and 82% in fish muscle tissue. %LOD results which fall outside of this range are considered aberrant. A high %LOD result may be due to inclusion of water droplets during tissue sampling in the field while a low %LOD result may be the result of compression of the tissue during the sampling procedure which results in a loss of moisture from the tissue.

Irregular %LOD results have been replaced with a value of 80% which is considered typical for %LOD of muscle tissue in fish. These corrections affect the wet weight concentrations of total Hg; there is no affect upon the dry weight total Hg concentrations. Original %LOD values can be found on the wet_wt-dry_wt sheet in this workbook.

Detection Limit: 16 ng/g (ML) MDL=4 ng/g The MDL was determined based on 7 replicates of analytical blanks (98% confidence level) and a 20 mg dry sample size.

For reporting purposes results will be flagged below the ML which is considered a practical quantitation limit.

Estimated Uncertainty: The estimated uncertainty of this method has been determined to be ± 13%

Results authorized by Dr. Robert J. Flett, Chief Scientist

QUALITY DATA

Blanks		pg of MeHg in whole ethylation EPA vial	Gross Peak Area	Mean Ethylation Blank (ng/L)
	Ethylation blank (H_2O+Reagent)	0.22	713	0.01
	Mean Eth. Blank (last 30 runs)	0.33		0.01

Blanks		Net pg MeHg in whole Ethylation EPA vial	Gross Peak Area	Equiv. CH Hg Conc. - based on current batch mean weight (0.0038g) of dry sample, ng/g (Biota)	
	Method Blank 1	0.22	1426	4.890	
	Method Blank 2	0.07	921	1.444	
	Method Blank 3	0.09	1013	1.968	
	Mean Method Blank	0.13		2.768	

Standards		MeHg Standard Added to Ethylation EPA Vial (pg CH_3Hg)	Gross Peak Area	Net Corrected MeHg Std Calibration Factor (units / pg)	RSD of MeHg Standard
	Mean Value			5414	3.7

	Sample Identification	Sample Type	Gross Peak Area	% CH_3Hg Recovery Used for Calculations	Dry Sample Mass (g)	% Wt. Loss On Drying	Net CH_3Hg as Hg (ng/g-Dry-Wt)	Net CH_3Hg as Hg (ng/g-Wet-Wt)	CH_3Hg Recovery (%)
Spike Recovery Matrix Spike (MS) and Matrix Spike Duplicate (MSD)	AN3-22-NRPK (FID 22)	MS4	432573	100%	0.004	82.3	3049	539	80.9
	AN3-22-NRPK (FID 22)	MS4D	435572	100%	0.004	82.3	2867	507	80.1
	Mean of Recoveries								**80.5**
QC Samples	Dorm-4 ID1501 (355± 28 ng/g)		476113	100%	0.038	3.3			92.4
	Dorm-4 ID1501 (355± 28 ng/g)	**Repeat Aliquot**	473875	100%	0.038	3.3			91.9
	Mean of Dorm-4						327		**92.2**
Alternate Source Standard (A.S.S.)	A.S.S. - Alfa ID1302 (1000 ng/L)		163405	100%			1022	<- Net CH_3Hg as Hg (ng/L)	**102.2**

LAB ID	Sampling Details	Sample ID	Date Sampled	Sample Type	Gross Peak Area	% CH_3Hg Recovery Used for Calculations	Weighed Dry Sample Mass (g)	**% Wt. Loss On Drying	Net CH3Hg as Hg (ng/g) Dry Wt. [recovery corrected] As Analyzed	Net CH3Hg as Hg (ng/g) Wet Wt. [recovery corrected] As Calculated
85214	P1-21-NRPK	FID 21	October 18, 2017		31818	80.5	0.0022	80	**455**	**72.0**
85215	AN3-22-NRPK	FID 22	October 19, 2017		57827	80.5	0.0038	82.3	**490**	**86.6**
85216	AN3-23-NRPK	FID 23	October 19, 2017		268602	80.5	0.0046	80	**1920**	**323**
85217	AN4-24-NRPK	FID 24	October 19, 2017		344315	80.5	0.0043	81.1	**2630**	**496**
85218	AN4-25-NRPK	FID 25	October 19, 2017		178997	80.5	0.0028	81.0	**2080**	**394**
85219	AN5-26-NRPK	FID 26	October 19, 2017		225366	80.5	0.0036	80	**2050**	**313**
85220	AN5-27-NRPK	FID 27	October 19, 2017		243737	80.5	0.0047	80	**1700**	**284**
85221	AN6-28-NRPK	FID 28	October 19, 2017		154973	80.5	0.0039	81.3	**1320**	**246**
85222	AN6-29-NRPK	FID 29	October 19, 2017		298397	80.5	0.0039	80	**2480**	**435**
85223	AN6-30-NRPK	FID 30	October 19, 2017	DupA1	255983	80.5	0.0040	82.2	**2120**	**378**
85223	AN6-30-NRPK	FID 30	October 19, 2017	DupA2	219502	80.5	0.0037	82.2	**1940**	**346**

* : See 'Comments' section above for discussion.

Q:\Clients A-L\Hatfield Consultants - SHELL\2017(837)\Methyl Hg\MTBIOT112417XW1.xls

Dup : Duplicate - two subsamples of the same sample carried through the analytical procedure in an identical manner.

Appendix A5

Statistical Analyses of Fish Tissue Mercury Concentrations

A5.1 APPROACH

Linear modeling was used to compare the mercury concentrations in northern pike tissue by cohort in Jackpine Lake. Tissue mercury concentrations, fish ages, and whole-body weights were measured directly as part of the Program, whereas cohort was defined as the year of capture minus the estimated age of the fish.

Statistical modeling was conducted on the Age 2 and Age 3 fish only. Other age classes (i.e., Age 0-1 and Age 4 and greater) did not have sufficient numbers of individuals across all cohorts (Figure 3.9). The two age classes were modeled separately. The models considered two potential variables that could be associated with differences in mercury tissue concentration within an age class:

$$mercury\ concentration \sim weight + cohort$$

Weight was modeled as a continuous covariate whereas cohort was a categorical factor. The models were assessed by plots of residuals, fitted values, covariate values, and quantiles (normal Q-Q plot). The significance of the effects of the covariance of weight on tissue mercury concentrations was assessed by an F-test of the weight term in the linear model. The cohort-specific effects were assessed using simultaneous inference on the cohort-specific model parameters, which applied Tukey's all-pairwise comparisons while bounding the familywise error rate and adjusting for the effects of fish weight (Hothorn et al. 2008).

A5.2 STATISTICAL METHODS

Data compilation and statistical analyses were completed in R (www.r-project.org). The session and package information for the analyses were:

```
R version 3.4.4 (2018-03-15)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows 7 x64 (build 7601) Service Pack 1

Matrix products: default

locale:
[1] LC_COLLATE=English_United States.1252  LC_CTYPE=English_United States.1252
LC_MONETARY=English_United States.1252
[4] LC_NUMERIC=C                           LC_TIME=English_United States.1252

attached base packages:
[1] grid      stats     graphics  grDevices utils     datasets  methods   base

other attached packages:
 [1] openxlsx_4.0.17 FSA_0.8.19  car_3.0-0     carData_3.0-1   gridExtra_2.3
readxl_1.0.0    forcats_0.3.0   stringr_1.3.0
 [9] dplyr_0.7.4     purrr_0.2.4     readr_1.1.1     tidyr_0.8.0     tibble_1.4.2
ggplot2_2.2.1   tidyverse_1.2.1

loaded via a namespace (and not attached):
 [1] reshape2_1.4.3      haven_1.1.1         lattice_0.20-35     colorspace_1.3-2
yaml_2.1.18         rlang_0.2.0
 [7] pillar_1.2.1        foreign_0.8-69      glue_1.2.0          modelr_0.1.1
bindrcpp_0.2.2      bindr_0.1.1
[13] plyr_1.8.4          munsell_0.4.3       gtable_0.2.0        cellranger_1.1.0
rvest_0.3.2         psych_1.8.3.3
```

```
[19] rio_0.5.10        parallel_3.4.4     curl_3.2          broom_0.4.4
Rcpp_0.12.16       scales_0.5.0
[25] jsonlite_1.5      abind_1.4-5        mnormt_1.5-5      hms_0.4.2
stringi_1.1.7      cli_1.0.0
[31] tools_3.4.4       magrittr_1.5       lazyeval_0.2.1    crayon_1.3.4
pkgconfig_2.0.1    data.table_1.10.4-3
[37] xml2_1.2.0        lubridate_1.7.3    assertthat_0.2.0  httr_1.3.1
rstudioapi_0.7     R6_2.2.2
[43] nlme_3.1-131.1    compiler_3.4.4
```

A5.3 RESULTS

A5.3.1 Age 2 Northern Pike

One age-2 fish collected in 2015 was excluded from the analysis because it was an outlier in weight (1,830 g) and tissue mercury concentration (494 ng/g) relative to other age-2 fish. The linear model identified relationships between tissue mercury concentrations and both fish weight and cohort (Table A5.1). The model diagnostic plots did not identify any major concerns with the distribution of residuals or fitted values (Figure A5.1).

Table A5.1 ANOVA summary table for the linear model of tissue mercury concentrations for Age 2 pike.

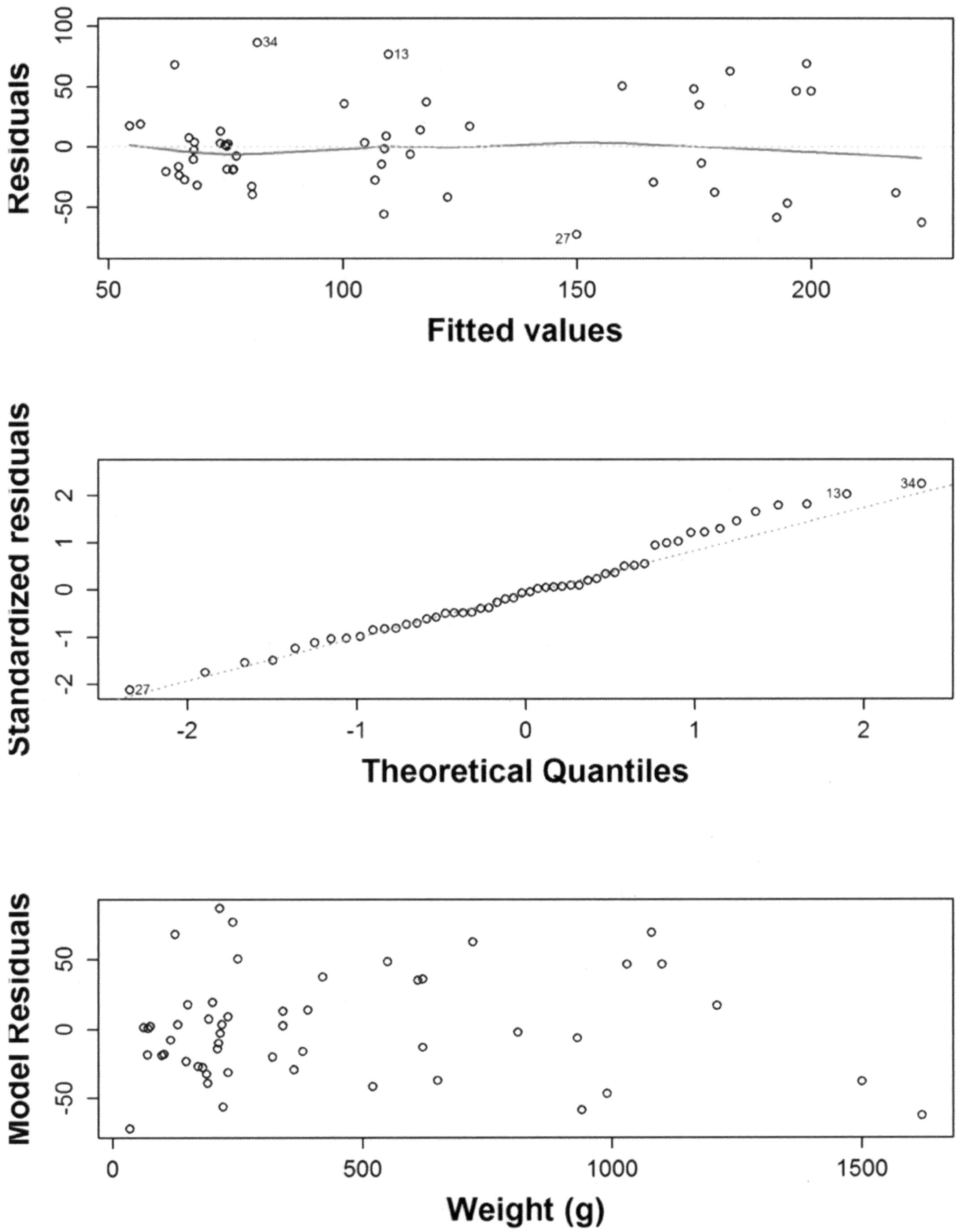
	Degrees of Freedom	Sum of Squares	Mean Squares	*F*	*p*
Weight	1	81,125	81,125	50.5	<0.0001
Cohort	5	49,317	9,863	6.1	0.0002
Residuals	45	72,361	1,608		

Table A5.2 shows the pairwise differences between cohorts from the model adjusted for fish weight, with confidence intervals for a 95% family-wise confidence level. Confidence intervals that do not include zero are marked in bold, and represent contrasts that are significantly different. The pairwise comparisons identified the 2012 and 2013 cohorts to have significantly higher tissue mercury concentrations than the 2010, 2014, and 2015 cohorts. No other significant differences were identified.

Table A5.2 Cohort pairwise differences for Age 2 pike, adjusted for fish weight.

Cohort Pairwise Contrast	Estimated Difference	Lower C.I.	Upper C.I.
2011 – 2010	51	-20	122
2012 – 2010	**102**	**21**	**183**
2013 – 2010	**100**	**16**	**185**
2014 – 2010	24	-43	92
2015 – 2010	11	-60	91
2012 – 2011	51	-16	118
2013 – 2011	50	-22	121
2014 – 2011	-27	-77	24
2015 – 2011	-40	-95	14
2013 – 2012	-1.6	-79	76
2014 – 2012	**-78**	**-139**	**-17**
2015 – 2012	**-91**	**-160**	**-23**
2014 – 2013	**-76**	**-144**	**-9**
2015 – 2013	**-90**	**-161**	**-19**
2015 – 2014	-13	-63	36

Figure A5.1 Model diagnostic plots for Age 2 fish.



A5.3.2 Age 3 Northern Pike

One age-3 fish collected in 2014 (fish 2014|JCL-8|140) was excluded from the analysis because its high mercury tissue concentration had substantial leverage on the overall model. The linear model identified relationships between tissue mercury concentrations and both fish weight and cohort (Table A5.3). The model diagnostic plots did not identify any major concerns with the distribution of residuals or fitted values (Figure A5.2).

Table A5.3 ANOVA summary table for the linear model of tissue mercury concentrations for Age 3 pike.

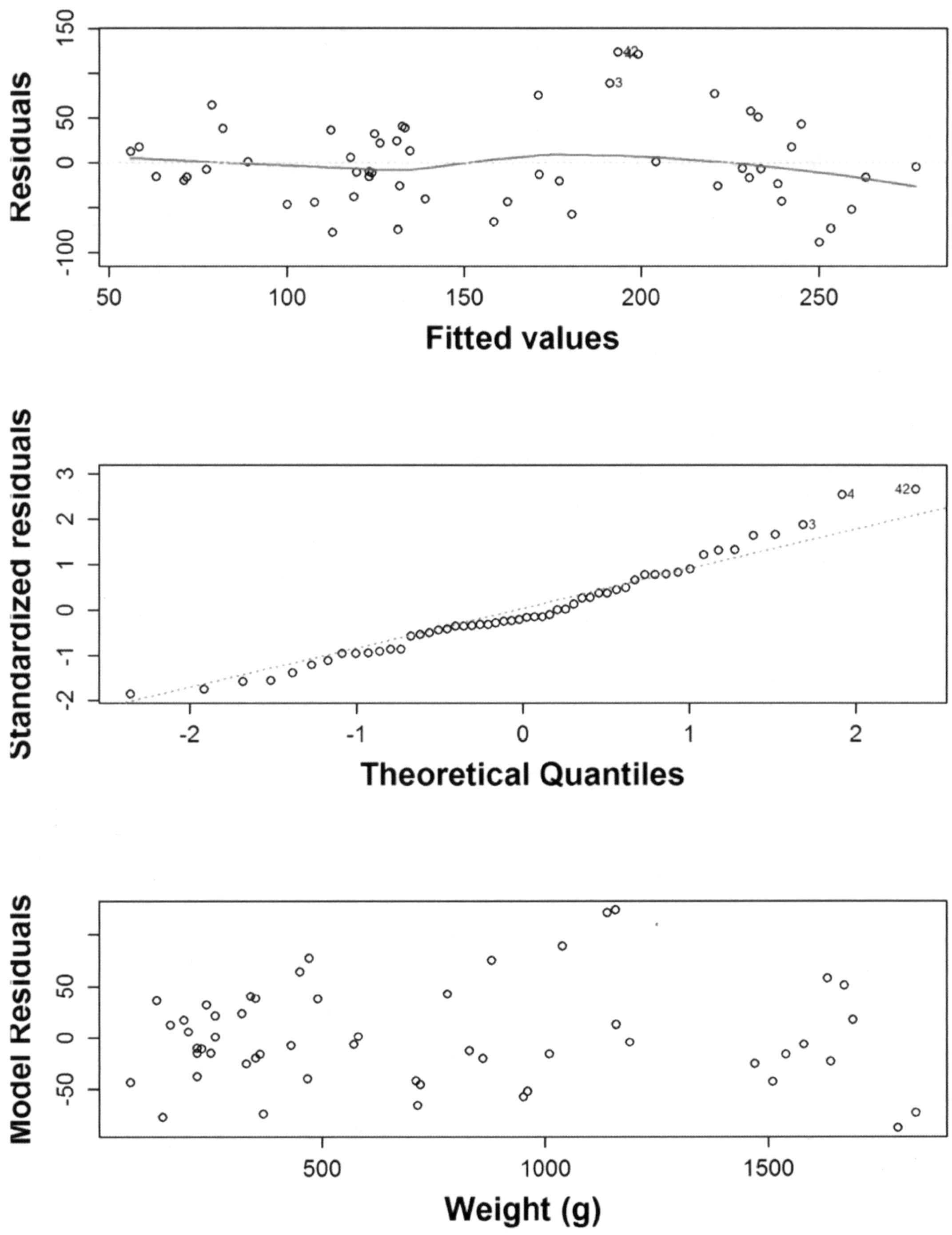
	Degrees of Freedom	Sum of Squares	Mean Squares	*F*	*p*
Weight	1	121,820	121,820	47	<0.0001
Cohort	5	93,158	18,632	7.2	<0.0001
Residuals	47	120,827	2571		

Table A5.4 shows the pairwise differences between cohorts from the model adjusted for fish weight, with confidence intervals for a 95% family-wise confidence level. Confidence intervals that do not include zero are marked in bold, and represent contrasts that are significantly different. The pairwise comparisons identified the 2012 cohort to have significantly higher tissue mercury concentrations than the 2009, 2010, and 2013 cohorts. No other significant differences were identified.

Table A5.4 Cohort pairwise differences for Age 3 pike, adjusted for fish weight.

Cohort Pairwise Contrast	Estimated Difference	Lower C.I.	Upper C.I.
2010 – 2009	**62**	**0.9**	**124**
2011 – 2009	66	-14	146
2012 – 2009	**140**	**71**	**209**
2013 – 2009	59	-10	127
2014 – 2009	58	-22	138
2011 – 2010	3.5	-79	86
2012 – 2010	**78**	**8**	**148**
2013 – 2010	-3	-72	65
2014 – 2010	-4	-85	76
2012 – 2011	74	-7	156
2013 – 2011	-7	-92	78
2014 – 2011	-8	-101	86
2013 – 2012	**-81**	**-157**	**-6**
2014 – 2012	-82	-168	3.8
2014 – 2013	-0.7	-86	85

Figure A5.2 Model diagnostic plots for Age 3 fish.



A5.4 REFERENCES

Hothorn T, Bretz F, Westfall P. 2008. Simultaneous inference in general parametric models. *Biometrical Journal* 50(3): 346–363.



Hatfield
CONSULTANTS
Environmental Specialists Since 1974






No Net Loss Lake Monitoring Program 2018 Technical Report

April 2019

Prepared for:
Suncor Energy Operating Inc.
Calgary, Alberta

#200 - 850 Harbourside Drive, North Vancouver, British Columbia, Canada V7P 0A3 • **Tel: 1.604.926.3261** • Fax: 1.604.926.5389 • **www.hatfieldgroup.com**

Hatfield
CONSULTANTS

NO NET LOSS LAKE MONITORING PROGRAM 2018 TECHNICAL REPORT

Prepared for:

SUNCOR ENERGY OPERATING INC.
150 - 6TH AVENUE SW
Calgary, AB
CANADA T2P 3E3

Prepared by:

HATFIELD CONSULTANTS
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3

APRIL 2019

SUN9032

VERSION 2.0

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AN	Angling
ADV	Acoustic Doppler Velocimeter
ADC	Acoustic Digital Current meter
AEP	Alberta Environment and Parks
AESRD	Alberta Environment and Sustainable Resource Development
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
BURB	Burbot
CCME	Canadian Council of Ministers of the Environment
CPUE	Catch per-unit-effort
DFO	Fisheries and Oceans Canada
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EPT	Ephemeroptera, Plecoptera, and Tricoptera
ETO	Ephemeroptera, Trichoptera, and Odonata
EF	Electro-fishing
EMSH	Emerald shiner
FHEC	Fort Hills Energy Corporation
FHELP	Fort Hills Energy L.P.
FiSH	Fisheries Sustainable Habitat Committee
FNDC	Finescale dace
FWI	Field Work Instructions
GN	Gillnetting
GoA	Government of Alberta
GPP	Generator Powered Pulsator
GPUE	Grams per-unit-effort
HADD	Harmful Alteration, Disruption, or Destruction of Fish Habitat
HEP	Habitat Evaluation Procedures
HN	Hoop netting
HSI	Habitat Suitability Index
HU	Habitat Units
IC	Inlet Channel
ISQG	Interim Sediment Quality Guidelines
JOSMP	Joint Oil Sands Monitoring Program
LKCH	Lake Chub

LL	Lake Level
LNDC	Longnose Dace
LNSC	Longnose Sucker
LZ	Littoral Zone
NNLL	No Net Loss Lake
NNLLDP	No Net Loss Lake Development Plan
NRDC	Northern Redbelly Dace
NRPK	Northern pike
NTU	Nephelometric Turbidity Units
MASL	Metres Above Sea Level
MT	Minnow Trap
OC	Outlet Channel
PAH	Polycyclic Aromatic Hydrocarbons
PIT	Passive Integrated Transponder
PZ	Pelagic Zone
QA/QC	Quality Assurance and Quality Control
QSP	Quality System Procedure
RPD	Relative Percent Difference
SDR	Stage-Discharge Relationship
SEOI	Suncor Energy Operating Inc
SI	Suitability Index
SN	Seine Netting
SOP	Standard Operating Procedures
SPSH	Spottail Shiner
SLSC	Slimy Sculpin
SMUs	Sample Mesohabitat Units
TDS	Total Dissolved Solids
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WHSC	White Sucker
WY	Water Year
YLPR	Yellow Perch

EXECUTIVE SUMMARY

Suncor Energy Operating Inc. (SEOI), on behalf of the Fort Hills Energy Corporation (FHEC), constructed the No Net Loss Lake (NNLL) on a terrace of the eastern bank of the Athabasca River to compensate for fish and fish habitat losses associated with the Fort Hills Oil Sands Mine Project (the Project). As part of the regulatory approvals for the Project, the Department of Fisheries and Oceans Canada (DFO) provided Authorization (AB00-517-2013) for the harmful alteration, disruption, or destruction (HADD) of fish habitat within the Fort Creek watershed. The Authorization stipulates that monitoring of proposed compensation habitat must be undertaken until the compensation lake is functioning as intended to the satisfaction of DFO.

Hatfield Consultants (Hatfield) prepared a five-year compensation monitoring plan that was submitted by SEOI on behalf of FHEC to DFO in September 2014. The monitoring plan was approved by DFO in December 2014. Post-construction monitoring in 2014 focused on monitoring the physical and chemical characteristic of the NNLL, the inlet creek (Creek A) and the outlet channel. The 2014-2015 Water Year (WY) was the first year of monitoring under the approved plan. This report presents a summary of results of the monitoring for the NNLL, Creek A and the outlet channel up to the end of the 2018 WY (November 1, 2017, to October 31, 2018).

Monitoring of compensation habitats follows a phased approach, initially sampling physical and chemical habitat variables, followed by incorporating monitoring activities that focus on successive trophic levels (i.e., aquatic organisms). The objectives of monitoring activities during the fourth year of monitoring were to:

- monitor surface hydrology in the NNLL, Creek A, and the outlet channel;
- monitor water quality in the NNLL, Creek A and the outlet channel and screen these results against published guidelines for the protection of aquatic life;
- monitor sediment quality in the NNLL and screen these results against published guidelines for the protection of aquatic life;
- monitor lower trophic levels of aquatic organisms (i.e., plankton, benthos, and macrophyte communities) in the NNLL;
- assess fish populations in the NNLL, Creek A, and the outlet channel; and
- determine habitat suitability for fish species present in the NNLL and the outlet channel.

Results of the 2018 WY hydrologic monitoring indicated that the water level of the NNLL fluctuated due to recurring beaver dam construction and removal at the lake outlet. No evidence of shoreline erosion or disturbance to the littoral zone was observed, indicating that the littoral zone of the NNLL was stable during the open-water season. The water level of the lake was above the invert elevation of the outlet channel (232 m) for the entire WY, which allowed for continuous flow to the outlet channel from the NNLL.

Results of continuous water quality monitoring indicated that water temperature in the NNLL was influenced by both air and groundwater temperatures and is well mixed, displaying little thermal stratification. Water temperature in both Creek A and the outlet channel are primarily influenced by groundwater. Conductivity values and seasonal trends were similar to 2016 and 2017. Dissolved oxygen (DO) concentrations in the NNLL were also similar to 2016 and 2017 values and remained within guidelines for the protection of aquatic life (GoA 2018). Under ice concentrations of DO in late winter indicated that suitable over-wintering habitat was available for fish in the NNLL. On June 19, the daily average DO concentration in the outlet channel at station OC1 (6.3 mg/L) fell below the chronic guideline for the protection of freshwater aquatic life (6.5 mg/L) and continued to fall to 5.2 mg/L (above the acute guideline of 5.0 mg/L) on June 21. Levels subsequently rose above chronic guidelines following removal of a beaver dam at the lake outlet on June 23. Although higher than previous years in summer, pH values remained within guidelines during the open-water period. Turbidity measured in the pelagic zone remained low (i.e., maximum of 1.53 NTU) during the open-water season and was comparable to previous years. Concentrations of all water quality variables in Creek A, the outlet channel and NNLL were below water quality guidelines (GoA 2018) in 2018. Results of winter sublethal toxicity testing of water did not indicate any inhibitory effects to aquatic life in the NNLL.

Similar to previous years, results of analytical sediment quality monitoring in the NNLL showed a guideline exceedance of Canadian Council of Ministers of the Environment (CCME) F3 (C16-C34) hydrocarbons at the pelagic station in fall; however, concentrations of F3 (C16-C34) hydrocarbons were comparable to other lakes in the region (i.e., Shipyard, Kearl, and Isadore's lakes). Sediment hydrocarbon concentrations were dominated by F3 and F4 hydrocarbons, which indicated the presence of bitumen in sediments common for many watersheds in the Athabasca oil sands region. Survival of both freshwater amphipods and midges in sediment from the littoral zone and midges in the pelagic zone was noticeably lower than laboratory controls; however, survival of amphipods in the pelagic zone was similar to laboratory controls. Despite the decrease in amphipod and midge survival, growth of both species was higher than the laboratory controls. Further, results of sediment chemistry and the increased proportion of amphipods and midges in the NNLL compared to previous years suggest that there is no inhibitory effect.

Results of the benthic invertebrate, plankton, and macrophyte community monitoring (i.e., lower trophic levels of aquatic organisms) indicated that the productivity of the lake, as well the presence of suitable fish habitat, should support the ongoing colonization of fish populations. A number of fish species were captured in the NNLL and the outlet channel in 2018 (northern pike, yellow perch, burbot, longnose sucker, lake chub, emerald shiner, spottail shiner and slimy sculpin). Fish captured in the NNLL and the outlet channel over the course of the monitoring program (i.e., 2015 to 2018) include: northern pike, yellow perch, burbot, longnose sucker, white sucker, lake chub, emerald shiner, spottail shiner, slimy sculpin, finescale dace, longnose dace, and northern redbelly dace. Presence of these species in the lake is consistent with ongoing fish colonization, and with upstream fish passage through the outlet channel. Similar to 2016 and 2017, no fish were captured in Creek A (Station IC1) in 2018, as the steeper gradients and increased flow velocity provide marginal habitat for fish. To date only one longnose sucker has been captured in Creek A (2015).

Results of methyl mercury testing in fish muscle tissue in 2018 indicated that 11 of the 28 fish sampled in the NNLL exceeded the guideline for subsistence fishers, while none exceeded the guideline for general consumers. The concentration of methyl mercury in northern pike in 2018 appears positively correlated with age, length and weight as guideline exceedances appear to be restricted to older (i.e., 3+ years) and larger fish. Concentrations of mercury in fish tissue from the NNLL were within the range of the Athabasca oil sands regional dataset as well as the range of other northern Alberta lakes not influenced by oil sand activities.

As of 2018, the NNLL and outlet channel are currently providing 903,540 Habitat Units (HU), which is a small decrease from 2017 (913,215 HU), but still greater than both the 869,778 HU predicted in the No Net Loss Lake Development Plan (NNLLDP) (Golder 2006) and the 2:1 compensation ratio specified in the DFO Authorization. HU provided by the NNLL, specifically in 2018, did not change from 2017 (i.e., 865,365 HU). An increase in percent cover by macrophytes in the littoral zone has resulted in offsetting changes in habitat suitability, whereby certain species' Suitability Index (SI) values decreased (e.g., lake chub, yellow perch and longnose sucker) while SI values for other species increased (e.g., brook stickleback and fathead minnow). With the exception of substrate (i.e., decrease in cobble, as fines settle and macrophytes colonize areas <1 m deep in the littoral zone), habitat quality for other variables in the NNLL remained relatively similar to that observed in 2017. In the outlet channel, total HU decreased in 2018 compared to 2017. The main limiting habitat variable in the outlet channel is channel unit (i.e., channel morphology type). A decrease in available pool habitat resulted in lower SI ratings for several species (i.e., lake chub, burbot, white sucker, brook stickleback and fathead minnow). This reduction in available pool habitat is likely attributable to low water levels in the outlet channel during the September 2018 survey related to beaver activity (i.e., repeated damming of the lake outlet), such that mesohabitats previously identified as pools were classified in 2018 as run habitat.

Two fish were recorded crossing the outlet channel Passive Integrated Transponder (PIT) Tag stations in 2018. A northern pike captured and tagged from the pelagic zone of the NNLL on August 16, 2018, crossed the upstream station on August 16, 2018, and the downstream station on August 17, 2018, suggesting downstream movement. A burbot captured and tagged from the OC2 study reach on September 18, 2018, was detected at the downstream station on September 26, 2018, also suggesting downstream movement. An additional 33 northern pike, one burbot and three yellow perch were tagged in the NNLL, and three burbot were tagged in the outlet channel in 2018. It is anticipated that the PIT Tag Antennas will provide insight into fish residence in the NNLL and migration between the Athabasca River, the outlet channel and the NNLL as more fish are tagged over time.

Overall the development of the NNLL has progressed at a rate anticipated in the NNLLDP. The biological colonization of the lake to date indicates that the physical and chemical characteristics of the lake are capable of supporting diverse fish populations. Three changes are proposed for year five of the monitoring program:

1. Discontinue fish and fish habitat sampling in Creek A during the September (fall) program given 2018 represents the third consecutive year of no fish captures. The steeper gradient and increased flow velocity in this section of Creek A provides marginal habitat for fish, which is consistent with environmental baseline studies conducted pre-development of the NNLL when no fish were captured in this reach of Creek A. Further, the habitat characteristics remain similar year to year given the stable and consistent flow pattern of Creek A. Fish passage will continue to be monitored in order to satisfy Conditions 3.12 and 3.3 of the DFO Authorization.

2. Conduct plankton monitoring in August to improve understanding of seasonal patterns of phytoplankton and zooplankton in the NNLL. 2018 represents the second consecutive year where increases in chlorophyll *a* were observed at Station PZ1 in August. Currently plankton monitoring occurs in March, May, July and September.

3. Engage Alberta Environment and Parks (AEP) to further investigate the possibility of repeat tissue sampling in the same fish to better track mercury concentrations in fish tissue over time. Currently the Fish Research Licence for the NNLL does not permit tissue sampling from fish that show evidence of previous tissue sampling. Collecting multiple samples from the same fish over time would enable assessments of methylmercury concentrations in fish from the NNLL over time (i.e., are concentrations increasing, decreasing or stable).

Further evaluation will occur at the end of the approved five-year monitoring program.

DISTRIBUTION LIST

The following individuals/firms have received this document:

Name	Firm	Hardcopies	CDs	Email	FTP
Sarah Aho	Suncor Energy Operating Inc.	-	-	✓	✓
Tom Wiebe	Suncor Energy Operating Inc.	-	-	✓	✓

AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of 2018 No Net Loss Lake Monitoring Program	20190219	Wade Gibbons Project Director	Tim Poulton Project Manager
2	Second version of 2018 No Net Loss Lake Monitoring Program	20190329	[signature] Wade Gibbons Project Director	[signature] Tim Poulton Project Manager

CONCORDANCE TABLE

Approval	Clause	Sub Clause	Clause Description	Report Section(s)
			General Requirements	
DFO	3.3		The comp lake shall provide fish habitat for a variety of species (i.e., Northern Pike, Yellow Perch, White Sucker, Burbot, Longnose Sucker, Pearl Dace, Brook Stickleback, Fathead Minnow, and Lake Chub), preserving or restoring the ecological functionality of the confluence of the mouth of Creek A.	2.1.8; 3.6.1; 3.6.2
DFO	3.3		The comp lake shall provide sufficient residence time to achieve summer water temperatures suitable for the fish species expected to use the lake.	3.2.1
DFO	3.3		The comp lake will provide sufficiently deep areas to provide overwintering habitat.	3.2.1; 3.6.1
DFO	3.4		Success at implementing the Plan shall be achieved when permanent fish habitat gains offset fish habitat losses at the comp ratio in all respects, and when the compensation fish habitat is functioning physically and ecologically as a self-sustaining system to the satisfaction of DFO.	3.6.1; 4.0
DFO	3.8	1	The target compensation ratio for compensation construction completed after the HADD of fish habitat occurs is two units of compensation habitat for each unit of fish habitat harmfully altered, disrupted or destroyed (2:1).	3.6.1; Appendix A7
DFO	3.11		The effectiveness of the compensation lake shall be evaluated through monitoring programs that will include, but may not be limited to, assessing fish utilization, diversity, density and productivity of fish populations, verification of fish HUs and Habitat Suitability Indices (HSI) models, aquatic vegetation, benthic invertebrates, seasonal water quality including dissolved oxygen, fish passage, sediment quality, water flow and water levels.	3.6.1; 3.6.2; 3.5.1; 3.4.1; 3.4.2; 3.2.1;
DFO	3.12		The Proponent shall ensure fish passage between the Athabasca River, the comp lake and the reaches of the tributaries flowing into the comp lake, with confirmed preconstruction connectivity, as specified in the No Net Loss Lake Development Plan, with all or any exceptions subject to DFO approval.	3.6.1; 3.6.2
			Monitoring Requirements	
DFO	4.2		The monitoring plan shall determine whether, and to what extent, the comp lake is functioning as expected and to the satisfaction of DFO. The monitoring plan shall include, among other factors, two main components: monitoring of affected habitats (i.e., Creek A), and monitoring of compensation habitat (i.e., comp lake and outlet channel).	1.3
DFO	4.4		The monitoring plan shall include confirmation of hydrological modeling used to design the comp lake, temperature and dissolved oxygen modelling.	3.1; 3.2.1
DFO	4.5		The fish habitat and bathymetry of the comp lake shall be mapped, and stratified sampling of the fish habitat in the comp lake shall be undertaken.	2.1.8; 3.6.1

CONCORDANCE TABLE (CONT'D.)

Approval	Clause	Sub Clause	Clause Description	Report Section(s)
			Monitoring Requirements (Cont'd.)	
DFO	4.6		The habitat variables used in the HSI models shall be measured in the detailed study areas (including all mesohabitat types). This will entail installation of temperature data loggers, measurement of pH and dissolved oxygen, mesohabitat mapping, substrate particle size sampling, macrophyte sampling, and measurement of the other variables used in the models.	3.2.1; 3.6.1, 3.4.2; 3.5.1
DFO	4.7		The comp lake shall be monitored for the designed stability of shorelines, bathymetry, the size and functionality of the littoral zone, as well as the riparian zone.	2.1.8; 3.5
DFO	4.9		Sampling shall occur at an appropriate time of year for each variable. The sampling protocol shall be approved by DFO. The number of years that monitoring is required and the number of replicates of each mesohabitat type sampled in the intensive study areas shall be determined by the Proponent and subject to approval by DFO. The Proponent shall commence reporting on the success of compensation one year after the comp lake has been physically constructed and connected to the Athabasca River.	1.3
DFO	4.10		Tissue from sport fish species inhabiting the comp lake shall be monitored for methylmercury.	3.6.3
DFO	4.17	1	As part of the monitoring plan, the Proponent shall design and conduct a comprehensive and ongoing ground water (with potential interaction with fish bearing water) and surface water quality as well as sediment quality monitoring programs of water/sediment leaving the Project comp lake area.	3.1; 3.2; 3.4.2; See 4.17 Annual Report
			Reporting Requirements	
DFO	4.3	1	The Proponent is responsible for the verification of the current version of the HSI models unless this task is, or will be undertaken on a regional scale, and the Proponent is participating meaningfully in the verification studies.	3.6.1 (and through the FISH Committee)
DFO	4.13		The Proponent shall submit to DFO annual reports on the Monitoring Plan for each reporting year (October 1 of any year to September 30 of the following year) on or before April 15 of the following calendar year. Each report shall incorporate all previous years' tables, figures, appendices, methods, analysis, discussion, as required to present the entire monitoring program in a single coherent report and shall include recommendations for changes to the monitoring program to better assess productive capacity in future years.	3.1; 3.2; 3.3; 3.4; 3.4.1; 4.0

1.0 INTRODUCTION

Suncor Energy Inc., Total E&P Canada, Teck Resources, and Fort Hills Energy Corporation (FHEC) are partners in the Fort Hills Energy L.P.(FHELP), a consortium that was established to develop the Fort Hills Oil Sands Mine and Bitumen Production Facility (the Project). FHEC (the Proponent), holds the regulatory approvals for the Project. Suncor Energy Operating Inc. (SEOI) operates the Project on behalf of FHEC.

The Project is located 90 km north of Fort McMurray, Alberta and started producing oil in the first quarter of 2018.

Development of the Project involves construction of temporary and permanent diversions of Fort Creek; construction of Fort Creek crossings and associated approaches; destruction of the bed and channel of Fort Creek; construction of site de-watering and drainage works; construction and operation of site de-watering and drainage works; construction and operation of associated sediment and erosion control works; construction and operation of fish habitat compensation works as required by Fisheries and Oceans Canada and associated site clearing and riparian vegetation removal. Authorized impacts to fish and fish habitat resulting from the works, undertakings, operations or activities associated with the Project include construction of the fish exclusion barrier in Fort Creek; dewatering of Fort Creek by construction of the operational Fort Creek Headwater Diversion; dewatering, re-alignment and re-channelization of portions of Creeks A, B and C; and works and undertakings associated with the construction of the water intake on the Athabasca River.

As part of the regulatory approval of the Project, Fisheries and Oceans Canada (DFO) provided an Authorization (No. AB00-517-2013) pursuant to Section 35(2) of the *Fisheries Act*. To meet these requirements, a No Net Loss Lake (NNLL) and outlet channel to the Athabasca River was constructed in the lower portion of the Creek A watershed, as per criteria outlined in the No Net Loss Lake Development Plan (NNLLDP) developed by Golder (2006) on behalf of FHEC. The NNLLDP quantified expected Project-related fish habitat losses and presented specific compensation plans to offset these losses. The NNLL construction activities were completed in October 2013 and filling of the lake commenced in the winter of 2013/14. Water began spilling to the outlet channel at the end of February 2014 and connectivity with the Athabasca River was established during the spring 2014 freshet.

The Authorization stipulates that monitoring of constructed compensation habitat must be undertaken until such time that permanent fish habitat gains at the prescribed compensation ratio have been achieved to the satisfaction of DFO (Condition 3.4 of the Authorization). DFO requires the Proponent to facilitate the studies and sampling necessary to demonstrate that the NNLL is functioning as a self-sustaining system, both physically and ecologically, as intended and to the satisfaction of DFO. As specified in Condition 3.11 of the Authorization, the effectiveness of the NNLL shall be evaluated through a monitoring plan that will include, but may not be limited to, measuring the rate of colonization and community structure of aquatic and riparian vegetation, benthic invertebrates and fish; verifying Habitat Units (HU) created for fish species; and assessing water quality, sediment quality, water levels, outlet channel discharge and the availability of suitable conditions for fish passage. As specified in Condition 4.1 of the Authorization, a monitoring plan for the NNLL, approved by DFO in December 2014, was developed to ensure compensation and monitoring clauses set forth in DFO Authorization AB00-517-2013 are satisfied (Hatfield 2014).

Annual compensation monitoring reports must be provided to DFO for the first five years of monitoring. Post-construction monitoring of surface hydrology and water quality occurred in 2014 (SEOI 2015); however, this report presents results of the fourth year of comprehensive monitoring of the NNLL, the inlet creek (Creek A) and the outlet channel.

1.1 BACKGROUND

The intent of the monitoring program is to ensure the NNLL is functioning properly to provide fish habitat, and provide fish passage between the Athabasca River, NNLL and Creek A. The program incorporated scientifically defensible sampling methods to:

- monitor the physical, chemical, and biological characteristics of the compensation habitats, to ensure they are progressing towards self-sustaining ecological systems;
- quantify habitat gains for fish populations, to confirm appropriate compensation has been provided to offset losses related to the development of the Project; and
- provide appropriate information to inform adaptive management decisions.

The primary objectives of the monitoring program are to:

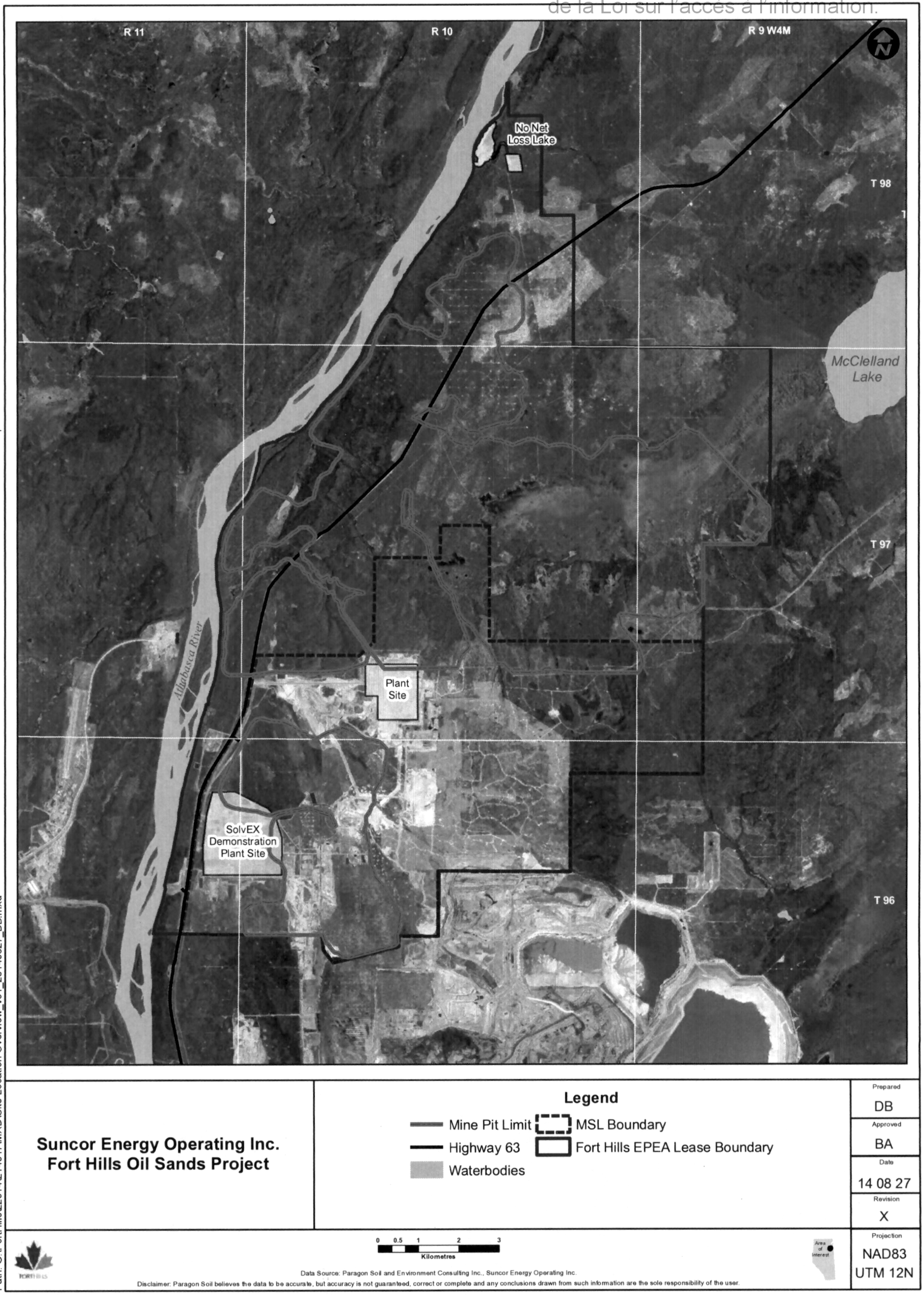
- quantify habitat units created by the NNLL and outlet channel to verify conformance with the *Fisheries Act* Authorization;
- monitor surface hydrology within the NNLL, the outlet channel and Creek A;
- monitor water and sediment quality in the NNLL and water quality in the outlet channel and Creek A, and screen these results against published guidelines for the protection of aquatic life (GoA 2018);
- monitor lower trophic levels of aquatic organisms in the NNLL (i.e., plankton, benthic invertebrate, and macrophyte communities) to ensure there is an available food supply and habitat for fish populations;
- monitor fish populations in the NNLL, outlet channel, and Creek A; and
- monitor fish tissue for methyl mercury concentrations and screen these results against published guidelines for human consumption.

The overall strategy for NNLL monitoring was discussed in detail in the NNLL Monitoring Plan (Hatfield 2014).

1.2 STUDY AREA

The Fort Hills Oil Sands Project is located 90 km north of Fort McMurray, Alberta on the east side of the Athabasca River (Figure 1.1). The NNLL has a watershed area of 2,415 ha (Figure 1.2) and is located on a terrace of the eastern bank of the Athabasca River that is approximately 150 m wide at each end, 500 m wide in the middle, and 1,400 m long. The terrace is bounded by the Athabasca River to the west, Creek A to the north, bedrock bluffs about 40 to 50 m high to the east, and a bedrock bluff about 5 to 10 m high to the south. The study area for the Fort Hills NNLL monitoring program included the NNLL, the outlet channel and Creek A (the inlet channel). A detailed description of the NNLL, Creek A and the outlet channel are provided in the following sections.

Figure 1.1 Development area for the Fort Hills Oil Sands Project and location of No Net Loss Lake, Alberta.



Map Number: 14017-140826-01

Path: G:\FortHills\z2014\z14017\MXD\Site Location Overview_v01_20140827_DB.mxd

Figure 1.2 Watershed area of the No Net Loss Lake, Fort Hills Oil Sands Project, 2017 WY.



1.2.1 No Net Loss Lake

The lake was constructed through excavation, with an elevated earthfill containment structure bordering the west side of the lake. The earthfill structure was required to avoid excessive excavation that may threaten valley wall stability, and to alleviate concerns with excavating below the Athabasca River water level. The NNLL has a surface area of 15.34 ha, a volume of 534,000 m^3, and a typical operating water level of 232.0 masl (metres above sea level). The maximum lake depth is 6 m, with a mean depth of approximately 3.5 m.

The NNLL was designed to provide habitat for brook stickleback (*Culaea inconstans*), fathead minnow (*Pimephales promelas*), lake chub (*Couesius plumbeus*), longnose sucker (*Catostomus catostomus*), northern pike (*Esox lucius),* pearl dace (*Margariscus margarita*), slimy sculpin (*Cottus cognatus*), yellow perch (*Perca flavenscens*), burbot (*Lota lota*), and white sucker (*Catostomus commersoni*) (Golder 2006). The littoral zone of the NNLL represents 36% of the total surface area of the lake and was contoured to create habitat complexity and diversity to support a variety of fish species (Golder 2006). The depth and volume of the lake were designed to maintain dissolved oxygen (DO) concentrations suitable to support overwintering fish.

1.2.2 Creek A and Outlet Channel

The outlet of the lake was constructed at the south end of the terrace, and discharges into the Athabasca River. The lake outlet channel was constructed as a meandering channel, with an average channel and wetted width of 6 m and 2.7 m, respectively, and length of 1,250 m. The outlet channel consists of a series of riffle and pool sequences, armored with substrate material consisting of well-graded, semi-rounded rocks, ranging in diameter from 100 mm to 300 mm. The outlet channel was constructed to have the appearance of a natural watercourse, and to provide similar habitat features. The design of the outlet channel is intended to allow fish passage between the Athabasca River and the lake during low-flow conditions (or discharges greater than 0.02 m^3/s for sportfish; Golder 2006), for the purposes of feeding, spawning, rearing, and overwintering.

Creek A (also known as the inlet channel) flows through the northern end of the Athabasca River terrace into the NNLL. Creek A has a drainage area of 14.6 km^2 and is primarily groundwater fed (i.e., approximately 80%; SEOI 2015).

1.3 STUDY DESIGN

The compensation monitoring program for the NNLL follows a five-year phased approach (Hatfield 2014). Post-construction monitoring (2014) focused on quantifying chemical and physical characteristics of the NNLL, Creek A and the outlet channel. The compensation monitoring program focused on quantifying the chemical characteristics and lower trophic levels in the NNLL. Year one also included quantification of HU created by the NNLL and outlet channel and an assessment of fish passage and fish populations in the NNLL, Creek A and the outlet channel.

1.3.1 No Net Loss Lake

The purpose of the compensation monitoring program is to evaluate the effectiveness of the NNLL in providing the intended habitat for fish, and to confirm that fish are using the habitat at or above the level predicted in the No Net Loss Development Plan (NNLLDP; Golder 2006). Adaptive management is used to inform each subsequent monitoring year, which may result in adjustments to the initiation and frequency of specific sampling activities. Monitoring of compensation habitat follows a phased approach, initially sampling physical and chemical habitat variables, followed by the incorporation of lower trophic levels of aquatic organisms, and higher trophic levels of biota. The sequence for expansion of a sampling program allows for the measurement of productivity as it develops over time and as fish populations develop. The frequency of monitoring is expected to diminish in the future as physical, chemical, and ecological attributes stabilize. In consultation with DFO, the monitoring components and program frequency after the fifth year will be determined based on results of the first five years of the program.

Monitoring of the NNLL in 2018 included the following components:

- Continuous monitoring of water level and seasonal in situ water quality;
- Seasonal analytical testing of water quality;
- Fall analytical testing of sediment quality;
- Monitoring of lower trophic level biota:
  - Seasonal plankton monitoring;
  - Summer assessment of the macrophyte community; and
  - Fall assessments of the benthic invertebrate community.
- Confirmation of assumptions made to identify the limiting Suitability Index (SI) variable for each fish species in the lake; and
- Summer characterization of fish species using the lake.

Scheduled sampling activities on an annual basis for the NNLL monitoring program are summarized in Table 1.1 (Hatfield 2014).

Table 1.1 Summary of sampling activities for monitoring of the No Net Loss Lake, Fort Hills Oil Sands Project.

Sampling Activity	Post-Construction Monitoring[1]	Year One	Year Two	Year Three	Year Four	Year Five
Standard Water Quality – Laboratory Analyses	Q	Q	Q	Q	Q	Q
In Situ Water Quality – Depth Profile	-	Q	Q	Q	Q	Q
Sublethal (Chronic) Toxicity Testing – Water	-	W	W	W	W	W
Continuous Monitoring of In Situ Water Quality	C	C	C	C	C	C
Lake Level Gauging	C	C	C	C	C	C
Sediment Depth	-	F	F	F	F	F
Macrophyte Community Assessment	-	S	S	S	S	S
Plankton Community Assessments	-	Q	Q	Q	Q	Q
Benthic Invertebrate Community Assessments	-	F	F	F	F	F
Fish Tissue Methyl Mercury Testing	-	S	S	S	S	S
Standard Sediment Quality Testing	-	F	F	F	F	F
Sublethal (Chronic) Toxicity Testing – Sediments	-	F	F	F	F	F
Stratified Fish Abundance Assessments	-	S	S	S	S	S

S = Summer; F = Fall; W = Winter; Q = Quarterly; C = Continuous.

[1] Post-construction monitoring was initiated in 2014 (SEOI 2015); year one to year five of the monitoring schedule is from the 2015 WY to the 2019 WY.

Key indicators of ecosystem health within the NNLL have been identified to determine whether the precursors to colonization of fish species typical of the Athabasca River watershed are present.

Key water quality variables included:

- Temperature – An influencing factor on biological composition and survival. High late summer temperatures are considered a limitation of habitat suitability for some fish species. Temperature stratification is a key biophysical characteristic of lakes/ponds.
- Dissolved Oxygen (DO) – An influencing factor of biological composition, particularly during late winter when anoxic conditions are known to result in die-off of species with high oxygen requirements.
- Electrical conductance (conductivity) – A basic indicator of overall ion concentration.
- Total dissolved solids (TDS) and dissolved organic carbon (DOC) – Indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively.
- pH – A measure of acidity/basicity. Biological communities are known to be affected by waters as they become either more basic or more acidic.
- Total suspended solids (TSS) – A variable strongly associated with other water quality variables, including total phosphorus, total aluminum, and numerous other metals (RAMP 2009). TSS is also an indicator of shoreline erosion.

- Ion balance – Ionic composition may be affected by discharges, seepages, changes in the water table, or by the relative influences of surface and groundwater contributions to lake water balance.
- Alkalinity – An indicator of the buffering capacity and acid-sensitivity of waters.
- Total phosphorus, total dissolved phosphorus, total nitrogen and nitrate+nitrite – Indicators of nutrient/trophic status in the lake.
- Total and dissolved aluminum –Total aluminum (for which water quality guidelines exist) has been demonstrated to be strongly associated with suspended solids. Dissolved aluminum also was assessed, as it more accurately represents biologically available forms of aluminum that may cause toxicity to aquatic organisms (Butcher 2001).
- Total boron, total molybdenum – Two metals found in predominantly dissolved forms in the oil sands area, which may be indicators of groundwater influence in surface waters.
- Total arsenic – A variable identified as having potential to be liberated or otherwise introduced to groundwater.

Key sediment quality variables included:

- Particle size distribution (clay, silt and sand) – Sediment particle size is an indicator of the depositional regime at a given station, and an important factor affecting organic chemical sorption.
- Total organic carbon – An indicator of organic matter in sediment, including hydrocarbons.
- Total hydrocarbons (Canadian Council of Ministers of the Environment [CCME] fractions + BTEX) – Indicators of the total hydrocarbon content of sediments, with each indicator (fraction) capturing hydrocarbon compounds of different molecular weights (specifically, number of carbon atoms), and concentrations of benzene, toluene, ethylbenzene and xylene (collectively called BTEX).
- Various PAH variables, including:
  - Total parent PAHs – A sum of concentrations of all non-alkylated PAHs measured in a given sample; and
  - Naphthalene – A volatile, low-molecular-weight PAH that may cause toxicity when dissolved in water.
- Metals – Only metals in sediment that exceed Government of Alberta (GoA) Sediment Quality Guideline (GoA 2018) values were presented.

Key physical variables included:

- Inlet and outlet access conditions – Physical performance of the inlet and outlet with regard to fish passage and physical stability.
- Water level – Fluctuations in water level may affect productivity, macrophyte abundance, fish passage, and lake retention time.
- Shoreline stability – Areas of shoreline with excessive erosion could negatively affect habitat quality in a number of ways. Erosional areas need to be documented and stabilized if they cause significant problems.

Key biological components, which support fish populations and the function of fish habitat, included:

- Plankton communities – A measure of lake trophic status and a food source for some fish and benthic invertebrate species.
- Benthic invertebrate communities – Indicator of ecosystem health and biological progression of the lake and assessed using variables such as abundance, taxa richness, diversity, and the proportion of tolerant and pollution-sensitive taxa in the community.
- Macrophyte communities – Important source of cover for fish in the littoral zone and provides spawning habitat for a number of fish species. Also provides habitat for invertebrate communities and epiphytic algae.

1.3.2 Creek A and Outlet Channel

The objective of monitoring activities for Creek A and the outlet channel is to ensure there is fish passage between the Athabasca River, NNLL and Creek A, to evaluate the effectiveness of the outlet channel in providing the intended habitat for fish, and to confirm that fish are using the habitat at or above the level predicted in the NNLLDP (Golder 2006).

Monitoring of Creek A and the outlet channel in 2018 included the following components:

- Continuous monitoring of water level and in situ water quality;
- Seasonal analytical testing of water quality;
- Fall assessment of fish habitat and fish passage;
- Fall characterization of fish species distribution and abundance; and
- Continuous monitoring of fish passage in the outlet channel via PIT Tag monitoring stations.

Scheduled sampling activities on an annual basis for Creek A and the outlet channel monitoring program are summarized in Table 1.2 (Hatfield 2014).

Table 1.2 Summary of sampling activities for monitoring of Creek A and the NNLL outlet channel, Fort Hills Oil Sands Project.

Sampling Activity	Post-Construction Monitoring[1]	Year One	Year Two	Year Three	Year Four	Year Five
Standard Water Quality Testing	Q	Q	Q	Q	Q	Q
Continuous Monitoring of In Situ Water Quality	C	C	C	C	C	C
Water Level Gauging	C	C	C	C	C	C
Stream Discharge Measurements	M	M	M	M	M	M
Fish Abundance and Habitat Assessments	-	F	F	F	F	F

F = Fall; Q = Quarterly; C = Continuous; m = monthly, during open-water period.

[1] Post-construction monitoring was initiated in 2014 (SEOI 2015); year one to year five of the monitoring schedule is from the 2015 WY to the 2019 WY.

2.0 METHODS

2.1 FIELD DATA COLLECTION

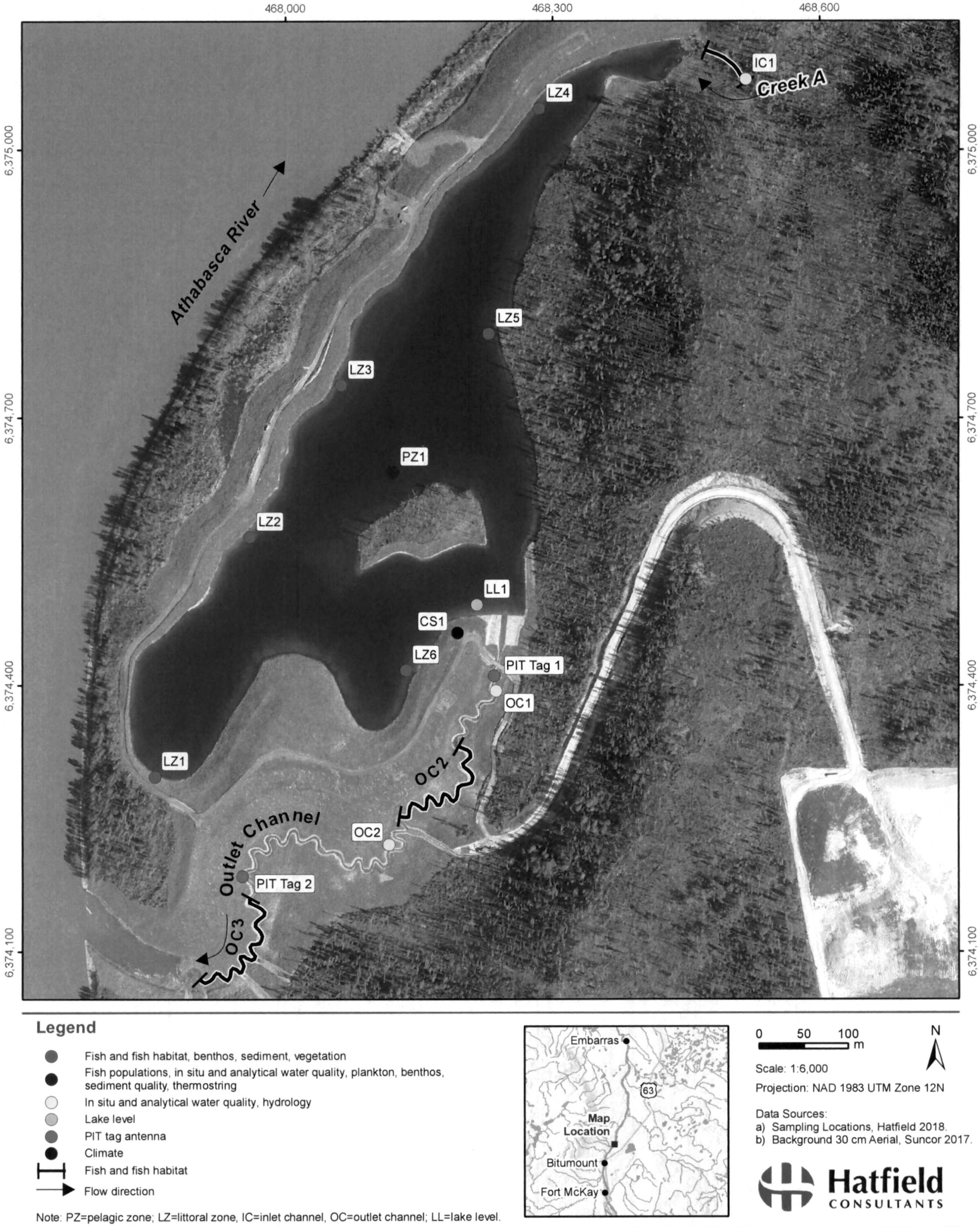
The 2018 WY monitoring program consisted of the following sampling activities:

- Continuous (hourly) climate monitoring at NNLL through the installation of a climate station equipped with various sensors and precipitation gauge;
- Continuous (hourly) monitoring of water level and discharge in NNLL, Creek A and the outlet channel through the installation of four calibrated pressure transducers equipped with dataloggers;
- Seasonal water quality sampling in the NNLL, Creek A and the outlet channel for the suite of variables measured by the Joint Oil Sands Monitoring Plan (JOSMP), including analyses of conventional variables, nutrients, organic compounds (i.e., naphthenic acids and total phenols), and total and dissolved metals including methyl mercury;
- Continuous (hourly) monitoring in the NNLL, Creek A and the outlet channel of temperature (°C), pH, conductivity (µS/cm), and dissolved oxygen (DO) (mg/L), and turbidity (NTU) (NNLL only) using multi-sensor equipped datasondes;
- Monthly depth profiles and in-situ water quality monitoring of temperature, DO, conductivity, and pH in the NNLL during the open-water season, plus one winter sampling event;
- Deployment of continuous-record dataloggers equipped to measure water temperature and light infiltration throughout the open-water season in the NNLL;
- Winter toxicity testing of water in the NNLL;
- Fall toxicity testing of sediment in the NNLL;
- Seasonal assessments of plankton communities in the NNLL;
- Summer assessment of aquatic macrophytes and riparian vegetation;
- Summer monitoring of fish populations of the NNLL using a variety of sampling techniques;
- Fall monitoring of fish populations of Creek A and the outlet channel to assess fish passage throughout the system;
- Continuous monitoring of PIT tag readers, installed August 2015 in the outlet channel to assess movement of tagged fish;
- Fall assessment of fish habitat of Creek A and outlet channel to assess habitat suitability of various fish species;
- Fall assessment of benthic invertebrate communities in the NNLL; and

- Fall sediment quality sampling in the NNLL for the suite of variables measured by the JOSMP, including analyses of particle size, carbon content, total metals, organic compounds (i.e., four-fraction hydrocarbons, total hydrocarbons, and BTEX), and target and alkylated polycyclic aromatic hydrocarbons (PAHs).

Locations of sampling stations in NNLL, Creek A (IC1) and the outlet channel according to monitoring type are presented in Figure 2.1 and Table 2.1. A field sampling protocols manual (Hatfield 2015) was prepared to standardize field sampling procedures across seasons and years. The field sampling manual presents detailed sampling methods and data management techniques for the NNLL monitoring program.

Figure 2.1 Locations of sampling stations by monitoring type in No Net Loss Lake, Creek A, and the outlet channel, Fort Hills Oil Sands Project, 2018 WY.



No Net Loss Lake Monitoring Program

K:\Data\Project\SUN9032\A_MXD\SUN9032_Fig2_1_NNLL_Monitoring_Plan_20190222_v_1_SS.mxd

Table 2.1 Sampling locations for the No Net Loss Lake Monitoring Program, Fort Hills Oil Sands Project, 2018.

Location	Station Name	Station Description	Monitoring Components	UTM Coordinates (NAD83 Zone 12)
No Net Loss Lake	LZ1	Littoral Zone, southwest end of lake	Fish and fish habitat, benthos, sediment, vegetation	467870.6374340
	LZ2	Littoral Zone, southwest side of lake	Fish and fish habitat, benthos, sediment, vegetation	467982.6374564
	LZ3	Littoral Zone, west side of lake	Fish and fish habitat, benthos, sediment, vegetation	468082.6374739
	LZ4	Littoral Zone, north end of lake	Fish and fish habitat, benthos, sediment, vegetation	468292.6375025
	LZ5	Littoral Zone, east side of lake	Fish and fish habitat, benthos, sediment, vegetation	468207.6374782
	LZ6	Littoral Zone, southeast end of lake	Fish and fish habitat, benthos, sediment, vegetation	468119.6374434
	PZ1	Pelagic Zone	Fish populations, in situ and analytical water quality, plankton, benthos, sediment quality, thermostring	468121.6374639
	CS1	Climate Station	Air temperature, atmospheric pressure, evapotranspiration, precipitation, relative humidity, snow depth, net radiation, wind direction, wind speed	468195.6374456
	LL1	South side of lake	Lake level	468271.6374537
Creek A	IC1	Inlet	In situ and analytical water quality, hydrology, fish and fish habitat	468517.6375079
NNLL outlet channel	OC1	Outlet of NNLL	In situ and analytical water quality, hydrology, Pit tag antenna	468236.6374394
	OC2	Outlet channel, downstream of road	In situ and analytical water quality, hydrology, fish and fish habitat	468116.6374222
	OC3	Near confluence to Athabasca River	Fish and fish habitat, pit tag antenna	467844.6374130

PZ = pelagic zone; LZ =littoral zone, IC = inlet channel, OC = outlet channel; LL = lake level.

2.1.1 Climate

To provide context for the continuous hydrologic data and water temperature data, a comprehensive 10 m tower climate station equipped with Campbell Scientific datalogger was installed on June 10, 2015. The climate station was programed to collect data at 60-minute intervals and recorded the following variables:

- Air temperature (°C);
- Relative humidity (%);
- Atmospheric pressure (kPa);
- Net radiation (W/m^2);
- Wind speed and direction (m/s, deg);
- Snow depth (cm); and
- Precipitation (mm).

Near real-time data were transmitted to a database on a daily basis via a remote telemetry connection and monitored for anomalies.

2.1.2 Surface Hydrology

The hydrology component of the NNLL monitoring program consists of four monitoring stations, the NNLL (LL1), the NNLL Lake outlet station (OC1), the channel downstream the NNLL outlet (OC2), and the NNLL Creek A inflow (IC1) (Figure 2.1). Monitoring at these stations was conducted continuously, throughout the water year (WY = November 1, 2017 to October 31, 2018), using a calibrated pressure transducer (Keller Accu-level) connected to an Optimum Instruments DSL400 data logger. Water level data for LL1, OC1, OC2, and IC1 was recorded year-round, at 15-minute intervals, and transmitted to a database on a daily basis via a cellular telemetry connection. Also transmitting daily via the cellular telemetry are daily photos of NNLL from an all-weather CC640 digital camera attached to the climate station.

Eight manual surveys of water surface elevation and discharge measurements were conducted in the 2018 WY to further refine the stage discharge relationship. Procedures for conducting water level surveys were derived from standards published by BC Ministry of Environment (BC MOE 2009). Water level elevations were measured with an automatic level, to the nearest 0.001 m. Each survey consisted of two sets of measurements, with an acceptable level difference of <0.004 m between the two sets. Surveys were conducted using three independent benchmarks as elevation controls at each station.

Procedures used for streamflow measurements were consistent with Water Survey of Canada (WSC 2001), United States Geological Survey (USGS 1982), and BC MOE (BC MOE 2009) recommendations and protocols. Measurement standards are summarized below:

- Number of verticals: minimum of 20, or at a spacing of 0.05 m in small streams;
- Number of velocity observations for an open-water vertical measurement:
  - Where depth is 0.75 m or less, one observation is made at 60% of the depth below the surface; and

   - For depths greater than 0.75 m, observations are made at 20% and 80% of the depth below the surface.

- Number of vertical readings for a measurement under ice: the same procedure is used for under-ice and open-water velocity observations, with the exception that velocity is measured at 50% of the under-ice depth for verticals less than 0.75 m;

- Under-ice velocity observations collected at 50% of the effective depth are subject to a velocity correction of 0.88 to account for the confining influence of the ice. Verticals measured with two velocity measurements are not subjected to any velocity correction; and

- Velocity averaging: 40-second averages were collected for all meters, including the Sontek FlowTracker ADV (Acoustic Doppler Velocimeter), March McBirney Flo-Mate 2000 (electromagnetic meter), and Hach FH950 Velocity Flow Meter (electromagnetic meter).

Downloading, maintenance, and servicing of automated monitoring equipment was conducted during each field visit. The hydrologic monitoring stations were equipped with cellular telemetry to provide near real-time data to the Aquarius Time-Series® Version 3.10.71 (Aquatic Informatics) software database, managed by Hatfield, to ensure data quality and consistency between station visits.

2.1.3 Water Quality

2.1.3.1 In Situ Water Quality

Continuous (15-minute intervals) in situ monitoring of temperature (°C), DO (mg/L), conductivity (µS/cm), and pH (pH units) was conducted using a datasonde equipped with a multi-sensor (EXO2 sonde) from May 11 to October 15 in the NNLL, from May 10 to December 12 in Creek A and May 10 to November 26 in the outlet of the NNLL (Figure 2.1). The datasonde at the pelagic station of the NNLL was deployed from a EMM68 Buoy to a depth of approximately one meter and also monitored chlorophyll *a* (µg/L) and turbidity (NTU) in addition to the above mentioned variables. The datasondes in the inlet and outlet channels were secured to the bottom and tethered to the hydrology stations.

Data from the datasondes were collected at 15-minute intervals and transmitted to a database on a daily basis via a remote telemetry connection. Monthly downloading, servicing, cleaning, and calibrating of the datasondes occurred during the hydrologic field visits.

Light penetration and water temperature were measured at the surface and at one-metre depth intervals in the NNLL, using near-continuous dataloggers. The loggers measured luminous power in lux, which is limited to wavelengths perceived by the human eye. Measuring visible light penetration through the water column provides an estimate of the maximum depth where significant photosynthetic activity may occur (i.e., the euphotic zone). Temperature (°C) was measured concurrently with light penetration using the same dataloggers to monitor thermal stratification of the lake. Data were recorded every 15 minutes from May 11 to October 16 and downloaded monthly using Hoboware® software.

A YSI PRO DSS multi-meter was used to collect depth profile measurements of DO (± 0.01 mg/L), temperature (± 0.01°C), pH (±0.01 pH units), and conductivity (± 0.01 µS/cm) at the surface (0.3 m) then one-metre intervals through the water column at station PZ-1 in March, May, July, August, and September; the exception being March where profile measurements were collected under the ice (i.e., no surface measurement). At the Lake surface, supplemental measurements of DO were collected using a LaMotte portable Winkler titration kit, and temperature, pH, and specific conductivity were collected with a calibrated multi-meter Hanna pen to confirm the accuracy of the YSI multi-meter.

2.1.3.2 Analytical Water Quality

No Net Loss Lake

Seasonal water quality sampling of the JOSMP standard analytical package (Table 2.2) was conducted at the pelagic station of the lake (PZ1) on March 14, May 11, July 19, and September 19, 2018. The water quality sampling station was accessed by boat in spring, summer, and fall, and by drilling a hole through the ice using a gas-powered auger in winter.

During each sampling event, one composite water sample was collected from the lake, with equal volumes of water collected from one-metre depth intervals, using a Van Dorn sampler. The Van Dorn sampler was cleaned with a metals-free soap (i.e., Liquinox), then triple-rinsed with ambient lake water prior to deployment.

Water samples were collected, filtered, and preserved in labeled bottles according to protocols specified by the laboratory and submitted to ALS Environmental (ALS) in Fort McMurray for analyses at ALS Edmonton.

Outlet Channel and Creek A

Surface water samples were collected seasonally at the three channel stations (IC1, OC1 and OC2) on March 14, May 11, July 19, and September 19, 2018. Water quality variables measured were the same as those measured at NNLL (with the exception of chlorophyll *a*) and listed in Table 2.2. Samples were collected by submerging each sample bottle to a depth of approximately 0.3 m, uncapping and filling the bottle, and recapping the bottle at depth. The ultra-trace mercury bottle was triple-rinsed using this procedure prior to the final sample collection, following guidance from the analytical laboratory; all other bottles were filled directly without rinsing.

Samples were collected, filtered and preserved in labeled bottles and submitted to ALS in Fort McMurray for analyses.

Table 2.2 Water quality variables analyzed in No Net Loss Lake, Creek A and the lake outlet channel, Fort Hills Oil Sands Project, 2018.

Group	Variable	
Conventional variables	Colour	Total dissolved solids (TDS)
	Dissolved organic carbon (DOC)	Total hardness
	pH	Total organic carbon (TOC)
	Conductivity	Total suspended solids (TSS)
	Total alkalinity	Temperature
	Dissolved oxygen	Hardness ($CaCO_3$)
Major ions	Bicarbonate	Potassium
	Calcium	Sodium
	Carbonate	Sulphate
	Chloride	Sulphide
	Magnesium	
Nutrients	Nitrate+nitrite	Total phosphorus – total
	Ammonia nitrogen	Total dissolved phosphorus
	Total Kjeldahl nitrogen	Chlorophyll *a* (NNLL only)
Biological oxygen demand	Biochemical oxygen demand	
Organics	Naphthenic acids	Total recoverable hydrocarbons
	Oilsands extractable	CCME Fractions 2 to 4 and BTEX (Benzene, Toluene, Ethylbenzene, Xylene)
	Total phenolics	
Total and dissolved metals	Aluminum (Al)	Molybdenum (Mo)
	Antimony (Sb)	Rhenium (Re)
	Arsenic (As)	Rubidium (Rb)
	Barium (Ba)	Silicon (Si)
	Beryllium (Be)	Selenium (Se)
	Bismuth (Bi)	Silver (Ag)
	Boron (B)	Strontium (Sr)
	Cadmium (Cd)	Tellurium (Te)
	Cesium (Cs)	Thallium (Ti)
	Chromium (Cr)	Thorium (Th)
	Cobalt (Co)	Tin (Sn)
	Copper (Cu)	Titanium (Ti)
	Gallium (Ga)	Tungsten (W)
	Iron (Fe)	Uranium (U)
	Lead (Pb)	Vanadium (V)
	Lithium (Li)	Yttrium (Y)
	Manganese (Mn)	Zinc (Zn)
	Nickel (Ni)	Zirconium (Zr)
	Mercury (Hg, ultra-trace)	Methylmercury (CH_3Hg)

2.1.4 Toxicity Testing

Sublethal toxicity testing was conducted in water and sediment from the NNLL in winter and fall, respectively. The winter water sample was collected on March 14, 2018 at the deepest portion of the NNLL in the pelagic zone (Figure 2.1) from 0.2 m below the ice surface. A composite of grab samples was collected for a total of 20 l of water and poured into non-toxic polypropylene pails. The pails were shipped to Maxxam Analytics Inc. in Edmonton for the following analyses:

- 72-hour growth inhibition test using a freshwater alga (*Pseudokirchneriella subcapitata*) (Environment Canada 2007);
- Seven-day reproduction and survival test using a freshwater invertebrate (*Ceriodaphnia dubia*) (Environment Canada 2007); and
- Seven-day larval growth and survival test using fathead minnow (*Pimephales promelas*) (Environment Canada 2011).

Fall sediment sampling was conducted on September 20, 2018 using a 6" x 6" Ekman grab (0.023 m^2) sampler. As per the protocols described in Environment Canada (2013), five replicate samples were collected from each of the littoral pelagic zones. Five littoral stations were sampled, with each station representing one replicate sample, from water depths ranging from 0.4 m to 2.2 m (Figure 2.1). At the pelagic station, five separate grabs were collected, each grab representing one replicate, from a water depth of 6.2 m. Prior to sampling, the pan, spoon, and Ekman grab were washed with metal free soap (Liquinox®) and rinsed with ambient water. Samples were transferred to a stainless-steel pan and then into 1-L containers (provided by the laboratory) for shipping to Maxxam Analytics Inc. in Edmonton for the following analyses:

- 14-day static test for survival and growth in sediment using a freshwater amphipod (*Hyalella azteca*) (Environment Canada 2013); and
- Ten-day static test for survival and growth in sediment using the larvae of freshwater midges (*Chironomus dilutes*) (Environment Canada 1997).

2.1.5 Plankton Communities

Seasonal plankton surveys were conducted on March 14, May 11, July 19 and September 19, 2018, in the deepest portion of the NNLL (Figure 2.1). Plankton samples were submitted to ALS in Winnipeg, MB for taxonomic and biomass analyses.

2.1.5.1 Phytoplankton

Phytoplankton samples were collected as a composite from below the surface of the water and within the euphotic zone (1 m and 2 m) using a Van Dorn sampler. Two grabs were collected in each season and transferred to a clean 19-L polyethylene bucket and mixed into one composite sample. Prior to sampling, the Van Dorn sampler was rinsed in ambient water to remove any clinging material. The composite sample was then transferred to a 500-mL plastic container and preserved with approximately 15 drops of Lugol's solution.

2.1.5.2 Zooplankton

Zooplankton samples were collected from a composite of two vertical tows at a water depth of 5 m using a Wisconsin net. Prior to initiating the vertical tows, the Wisconsin net was soaked in lake water for two minutes and rinsed with ambient water to remove any clinging material. Once the zooplankton bucket was attached to the net it was lowered to a depth of 5 m in a vertical position. The net was then raised to the surface at a continuous rate of approximately 0.5 m/s to minimize avoidance of the net by fast-swimming zooplankton. Once at the surface, the outer sides of the net were rinsed with ambient water to wash clinging zooplankton from inside the wall of the net to the zooplankton bucket. To avoid the accidental introduction of zooplankton to the sample, rinsing was carried out without splashing water into the net opening or without lowering the net opening below the water surface. The zooplankton sample bucket was then removed from the net and drained into a 500-mL plastic container. Zooplankton were then anesthetized with club soda and preserved with 50 mL of 85% ethanol.

2.1.6 Benthic Invertebrate Communities and Sediment Quality

2.1.6.1 Benthic Invertebrate Communities

Fall benthic invertebrate sampling was conducted at the NNLL on September 20, 2018. Samples were collected at five littoral stations and one pelagic station (Figure 2.1). Three subsample grabs were collected from each station for a total of 18 samples. Grab samples were collected from water depths ranging from 0.4 m to 3 m, representative of the littoral zone, and a depth of 6.2 m in the pelagic zone using a 6" x 6" Ekman grab (0.023 m^2). For each grab, the Ekman jaws were opened over a box sieve (250-µm mesh size) and rinsed with ambient water to remove sediment. Sieved material from each grab was then transferred to a 1-L plastic container and preserved with 10% buffered formalin for shipping to Dr. Jack Zloty in Summerland, BC for taxonomic analysis.

Dr. Jack Zloty performed the sorting and taxonomic identifications of benthic samples. Samples were sieved again in the laboratory using a 250-µm mesh sieve to remove the preservative and any remaining fine sediments. The material retained by the sieve was elutriated using a flotation technique to separate organic material from sand and gravel, and invertebrates from organic material. Inorganic material was scanned under a magnifying lens and any remaining invertebrates were removed before discarding. The remaining organic material was separated into coarse and fine size fractions using a 1-mm sieve. The fine size fraction of large samples was sub-sampled using a modification of the method described by Wrona et al. (1982), in which fine materials were scanned for invertebrates with the aid of a dissecting microscope at a magnification of 6X to 10X. All sorted material was preserved for random checks of removal efficiency.

All benthic invertebrates were identified to the lowest practical taxonomic level, typically genus with the exception of Oligochaeta, which were identified to family.

2.1.6.2 Analytical Sediment Quality

Fall sediment quality sampling was conducted concurrently with benthic sampling at the NNLL on September 20, 2018 using sediment collected from all six littoral stations and the pelagic station (Figure 2.1). Sediment samples were collected for analyses of the suite of variables measured by JOSMP (Table 2.3) to provide direct comparisons with sediment quality of other lakes in the region.

One composite sample was collected in the littoral zone from grabs taken at depths of 0.4 m to 2.2 m from the six littoral stations, and another composite sample from a depth of 6.2 m at the pelagic station. A 6"x 6" Ekman grab (0.023 m^2) sampler was used to collect sediments. Grab samples were transferred to a stainless-steel pan and homogenized into a single composite sample with a stainless-steel spoon. Homogenized samples were transferred to two 250 mL and two 125 mL glass jars for metals analysis, CCME hydrocarbons F1 to F4, benzene, toluene, ethylbenzene, and xylene (BTEX), and PAH analyses.

Separate sediment samples were collected from each station and transferred to individual plastic bags and filled approximately 2/3 full for particle size and total organic carbon (TOC)/total inorganic carbon (TIC) analysis.

Prior to sampling, the pan, spoon, and Ekman grab were washed with metal free soap (Liquinox®), and rinsed with ambient water (i.e., lake water), then rinsed with hexane, acetone, and again with ambient water.

Table 2.3 Sediment quality variables analyzed in No Net Loss Lake, Fort Hills Oil Sands Project, fall 2018.

Group	Sediment Quality Variable	
Physical variables	Percent sand	Texture
	Percent silt	Moisture content
	Percent clay	
Carbon content	Total inorganic carbon (TIC)	Total organic carbon (TOC)
Total metals	Antimony (Sb)	Molybdenum (Mo)
	Arsenic (As)	Nickel (Ni)
	Barium (Ba)	Potassium (K)
	Beryllium (Be)	Selenium (Se)
	Cadmium (Cd)	Silver (Ag)
	Chromium (Cr)	Tin (Sn)
	Cobalt (Co)	Thallium (Th)
	Copper (Cu)	Uranium (U)
	Lead (Pb)	Vanadium (V)
	Mercury (Hg)	Zinc (Zn)
Organics	CCME 4-fraction total hydrocarbons:	BTEX (Benzene, Toluene, Ethylbenzene, Xylene)
	F1(C6-C10)	F3 (C16-C34)
	F2 (C10-C16)	F4 (C34-C50)
	Total hydrocarbons (C6-C50)	
Target PAHs	Acenaphthene	Dibenzothiophene
	Acenaphthylene	Fluoranthene
	Anthracene	Fluorene
	Benzo(a)anthracene	Indeno(1,2,3,cd)pyrene
	Benzo(a)pyrene	2-Methylnaphthalene
	Benzo(g,h,i)perylene	Naphthalene
	Benzofluoranthenes	Phenanthrene
	Biphenyl	Pyrene
	Chrysene	Retene
	Dibenzo(a,h)anthracene	

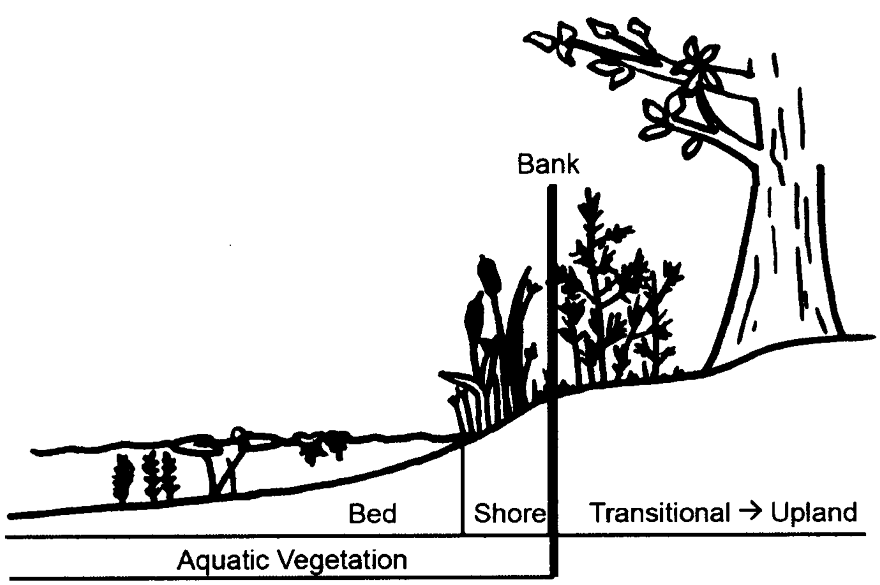
2.1.7 Vegetation Communities

2.1.7.1 Macrophyte Communities

The macrophyte communities of NNLL were surveyed on July18, 2018, at each littoral station to document macrophyte cover and density at the permanent macrophyte transects (Figure 2.1).

Aquatic macrophyte density was determined by estimating the abundance of macrophytes within a one-metre square floating quadrat positioned along a transect extending perpendicularly from the littoral zone. A benchmark (rebar post) was established at the ordinary high watermark of the NNLL at each littoral zone sampling location (LZ1 to LZ6). The ordinary high watermark of any lake is described as a distinct line formed by the normal, long-continued action or presence of surface water along the land at the edge of the lake (not affected by occasional periods of drought or flooding) (Government of Alberta 2015; Figure 2.2). Each transect was established in the field by anchoring the Eslon tape to the rebar post at the high watermark and extending the Eslon tape perpendicularly into the littoral zone of the lake as far as field personnel could wade or until macrophytes were no longer observed. Percent macrophyte cover beyond the wadeable depth (approximately 1.5 m to 3.0 m) was estimated visually with a sinking quadrate from a boat and with an underwater camera.

Figure 2.2 Schematic showing the location of the high watermark ("Bank") of a lake (taken from the Government of Alberta [2015]).

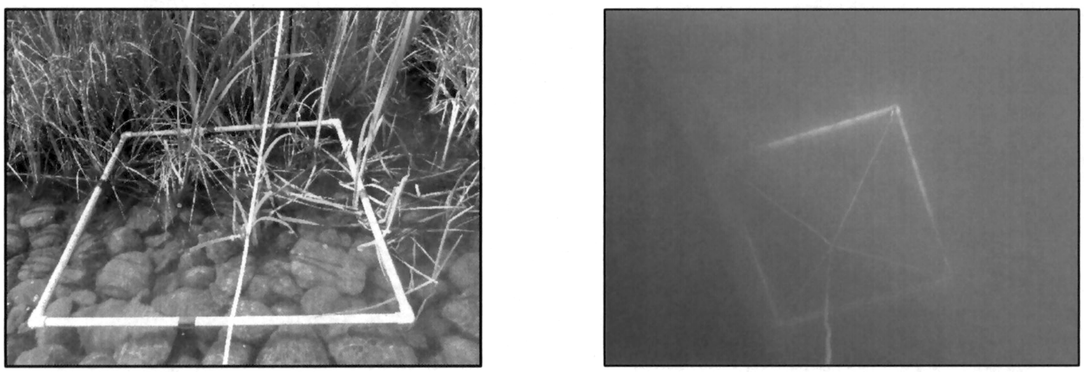


Quadrats were placed at 1-m intervals starting at the rebar post (the landward edge of the first quadrat starts at 0.0 m and the second starts at 1.0 m, etc.; Figure 2.3). At each one-metre quadrat, the following measurements are recorded:

- Distance along the transect (landward edge);
- Percent cover per species;

- Plant vigour, based on the following rating system:
    - 4 – excellent; green, healthy foliage;
    - 3 – good; mostly green, but with some faded or yellowish-brownish inclusions;
    - 2 – fair or average; faded or yellowish-brownish areas of foliage prominent;
    - 1 – poor; faded, yellowish-brownish areas dominate foliage; and
    - 0 – dead.
- Percent substrate composition – visual estimates of areal coverage by particles in standard size categories using the modified Wentworth classification system (Cummins 1962); and
- Water depth (measured at quadrat centre).

Figure 2.3 Example of 1-m^2 floating quadrat and 1-m^2 sinking quadrat positioned along a transect in No Net Loss Lake, Fort Hills Oil Sands Project.



Photographs and voucher specimens were collected if macrophytes could not be positively identified to species in the field using Royer and Dickinson (2007); Johnson et al. (1995); and CEMA (2009). Voucher specimens were placed in zip lock bags, pressed (if travel was required), refrigerated, and kept moist until identification could be verified.

2.1.7.2 Riparian Vegetation

Riparian vegetation surveys were conducted concurrently with the macrophyte community surveys at NNLL on July 18, 2018, at each of the littoral stations using the permanently established benchmarks (Figure 2.1).

Monitoring of riparian vegetation occurred in reclaimed areas and excluded existing forested landscapes (e.g., Transect LZ5). Riparian vegetation function was determined by estimating percent overhead cover by species within a 1.8 m radius (10 m^2) circular plots positioned along a transect extending landward and perpendicular to the ordinary high watermark. Each transect started at the benchmarks established for the macrophyte surveys at the littoral zone sampling locations (LZ1 to LZ6) and extended 30 m landward to a second benchmark. Transects were established by anchoring the Eslon tape to the benchmark at the high watermark and extending the Eslon tape perpendicularly to the second benchmark located 30 m landward (Figure 2.4).

Circular plots were positioned along each transect at 3.6 m intervals (plot centre to centre) for a total of eight 10 m^2 plots per transect. The centre of the first plot was positioned at 1.8 m using a bamboo stake manually pushed into the ground. A 1.8 m rope was anchored to the stake and used to define the boundary of the 10 m^2 circular plot. Within each plot, the following measurements were recorded:

- Distance along the transect (plot centre);
- Percent overhead cover; and
- Percent cover per species.

Photographs and voucher specimens were collected if plant species could not be positively identified to species in the field using Colberg and Abouguendia (2000); Inkpen and Ven Eyk (1998); and CEMA (2009). Voucher specimens were placed in zip lock bags, pressed (if travel was required), and refrigerated until identification could be verified.

Figure 2.4 Example of the 10 m^2 circular plot and the 30 m transect at No Net Loss Lake, Fort Hills Oil Sands Project.





2.1.8 Fish Populations and Habitat

2.1.8.1 Fish Habitat

No Net Loss Lake

Fish habitat surveys on the NNLL were, in part, described in previous sections related to the assessment of macrophyte communities (cover for fish) and, temperature and DO of the water. Procedures for the assessment of these characteristics are provided in sections 2.1.7.1, and 2.1.3.1, respectively. Data collection procedures were specifically developed to provide data that could be used to assess habitat suitability for fish species based on the regional Habitat Suitability Index (HSI) models outlined in Golder (2008), and to calculate the number of habitat units gained by the lake.

Shoreline stability and inlet and outlet conditions were assessed in conjunction with hydrometric assessments, with a focus on identifying impediments to fish passage following high-flow events and during annual low-flow conditions.

A qualitative visual survey of the outlet channel and the NNLL is conducted on a seasonal basis to assess shoreline erosion, particularly following flooding or large rain events. Observations related to soil erosion along the banks of the lake and channels, as well as connectivity between the lake and the outlet channel is visually assessed and documented.

Outlet Channel and Creek A

Fish habitat surveys on the outlet channel and Creek A (inlet channel) occurred in fall using procedures that are consistent with the FiSH Committee Field Sampling Protocols Manual (Hatfield 2013). These methods were specifically developed to assess habitat suitability for fish species based on the regional HSI models outlined in Golder (2008) and the number of habitat units gained by the outlet channel. The protocol for fish habitat surveys on channels is outlined in the following sections.

Reach Boundary Definition

The first step in the fish habitat assessment was to define the boundaries of the study reach. A study reach consists of a section of watercourse sufficiently long to include all mesohabitat types present in the outlet channel (or segment of the outlet channel). Ground-truthing of the reach was conducted prior to sampling to ensure that the reach boundaries incorporated all of the habitat types present in the stream segment; however, as a rule of thumb the study reach was 40 times the wetted width of the channel.

Once the study reach was delineated, the upstream and downstream boundaries were measured with a GPS and recorded. The reach length was measured along the thalweg (the deepest portion of the stream channel) using a hip chain.

Mesohabitat Classification

Once the study reach boundaries were defined, the reach was broken up into individual mesohabitat units. Each mesohabitat unit is defined by its habitat type, based on the classification system outlined in Table 2.4. Due to changing seasonal flow conditions, mesohabitat unit boundaries change from season to season and are measured accordingly. Similar to reach length measurements, mesohabitat unit lengths were measured with a hipchain along the thalweg. Key habitat elements of each mesohabitat unit were measured to provide an overall description of suitability for fish use. Fish habitat information recorded at each mesohabitat included observations of channel characteristics and fish cover components, and in situ measurements of water quality. A summary of key variables, measurement methods, and precision, is presented in Table 2.5.

Verification of an HSI model requires that, at a minimum, mesohabitat units selected for fish sampling are also assessed (Hatfield 2013). If one of the primary study objectives is to characterize aquatic habitat, then it is recommended that all mesohabitat units within the study reach are classified and measured; however, this additional effort is not required for assessing suitability indices.

Table 2.4 Classification of riverine mesohabitats as described in Golder (2008) used for the Fort Hills Oils Sands Project.

Habitat Type	Class	Abbreviation	Description
Riffle	-	RF	High velocity/gradient relative to run habitat; surface broken due to submerged or exposed bed material; shallow relative to other mesohabitat units; coarse substrate; usually limited instream or overhead cover for juvenile or adult fish.
Run	1	R1	Highest quality/deepest run habitat; generally deep/slow type; coarse substrate; high instream cover from substrate and/or depth (generally >1.0 m deep).
	2	R2	Moderate quality/depth; high to moderate instream cover except at low flow; generally deep/fast or moderately deep/slow type (generally 0.75 to 1.0 m deep).
	3	R3	Lowest quality/depth; generally shallow/slow or shallow/fast type; low instream cover in all but high flows (generally 0.5 to 0.75 m deep).
Pool	1	P1	Typically formed by downstream streambed hydraulic control, (e.g., riffle and not a beaver dam). Highest quality pool habitat based on size and depth; high cover due to instream features and depth; suitable holding water for large-bodied adults and physically suitable (although water quality may not be suitable) for overwintering (generally >1.5 m).
	2	P2	Moderate quality shallower than P1 with high to moderate instream cover except during low flow conditions; not suitable for overwintering large-bodied fish species.
	3	P3	Low quality pool habitat; shallow and/or small; low instream cover at all but high flow events.
Impoundment	-	IP	Typically pools that are formed behind beaver dams; tend to accumulate sediment/organic debris more than scour pools; may have cover associated with damming structure.

Table 2.5 Fish habitat variables and sampling methods used at Creek A and the NNLL outlet channel, Fort Hills Oil Sands Project, September 2018.

Habitat Variable	Measurement Method	Minimum Target Precision
Reach boundaries	GPS unit	± 5 m (approx.)
Channel and wetted widths	Measuring tape	± 0.1 m
Reach and mesohabitat lengths	Hip chain	± 0.1 m
Water velocity	Velocity meter	± 0.01 m/s
Substrate	Visual estimate	± 5%
Cover	Visual estimate	± 5%
Depth – discrete	Incremented depth staff	± 0.01 m
Photographs	Digital camera	5 megapixel
In situ DO – discrete	Winkler titration kit	± 0.1 mg/L
In situ water quality – discrete (temperature, pH, conductivity)	Handheld meter(s)	0.1 °C 0.1 pH 1 µS/cm
In situ water quality – continuous (DO, temperature, pH, conductivity)	Datasonde	± 0.01 mg/L 0.01 °C 0.01 pH 0.1 µS/cm

2.1.8.2 Fish Populations

Fish sampling was conducted in the NNLL between August 13 and 16, 2018. Sampling locations and fishing methods applied are presented in Table 2.6, Figure 2.5 and Figure 2.6. A Fish Research License was obtained from Alberta Environment and Parks (AEP) prior to sampling.

All minnow trapping and hoop netting consisted of overnight sets, to maximize the probability of fish captures. Gillnets were set during the day with soak times of approximately two hours. Each boat electrofishing pass consisted of a 100-metre long sampling transect.

Table 2.6 Sampling locations and fishing methods applied to No Net Loss Lake, Fort Hills Oil Sands Project, August 2018.

Station Type	Station Name	UTM Coordinates	Fishing Techniques[1]
Pelagic	PZ-1	12 V 468121 E 6374639 N	GN, AN
	PZ-2	12V 468271 E 6374537 N	GN, AN
Littoral	LZ-1	12V 467870 E 6374340 N	MT, HN, SN
	LZ-2	12V 467982 E 6374564 N	MT, HN, SN
	LZ-3	12V 468082 E 6374739 N	MT, HN, SN
	LZ-4	12V 468292 E 6375025 N	MT, HN, SN, AN
	LZ-5	12V 468207 E 6374782 N	MT, HN, SN,
	LZ-6	12V 468119 E 6374434 N	MT, HN, SN
	Lake Perimeter	-	EF
	Island Perimeter	-	EF, AN

[1] MT: minnow trapping; HN: hoop netting; EF: boat electrofishing; SN: beach seining; AN: angling; GN: gillnetting

Figure 2.5 Locations of minnow traps deployed at No Net Loss Lake, Fort Hills Oil Sands Project, August 2018.

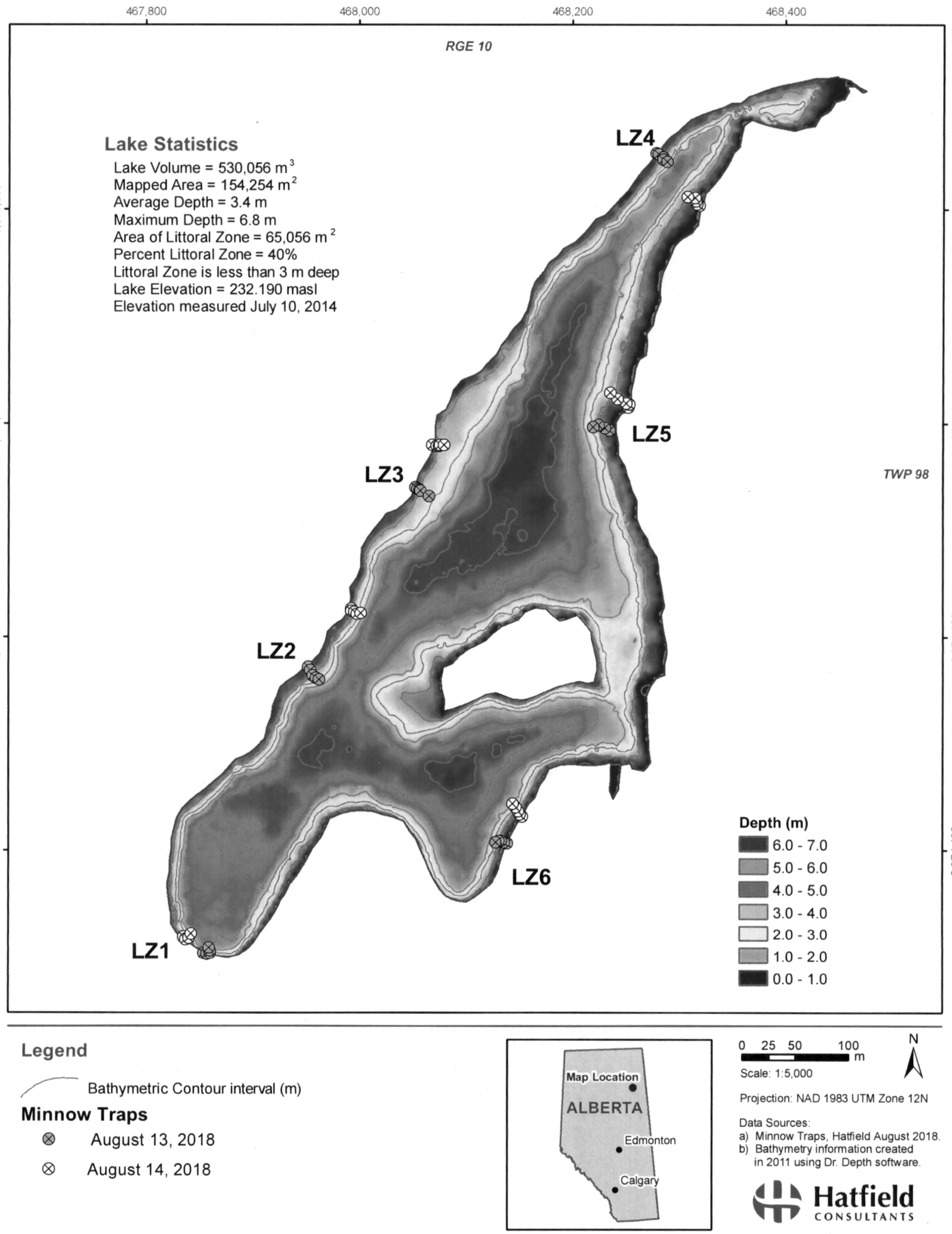
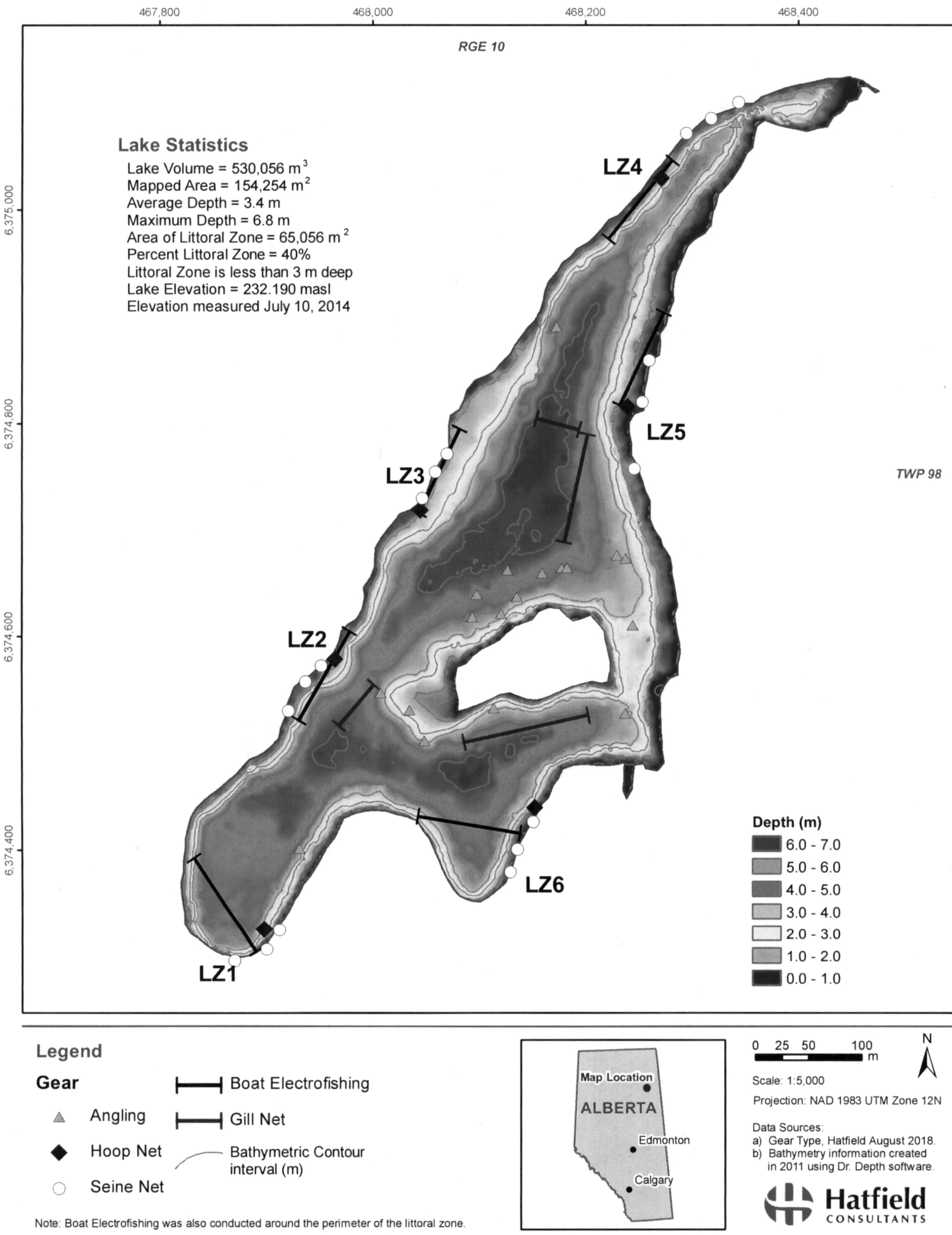


Figure 2.6 Fish sampling locations by gear type at No Net Loss Lake, Fort Hills Oil Sands Project, August 2018.



No Net Loss Lake Monitoring Program

K:\Data\Project\SUN9032\A_MXD\SUN9032_Fig2_6_NNLL_Electrofishing_20190222_v_1_SS.mxd

The Gee minnow traps that were used for collecting small-bodied species consisted of a standard mesh size of 6.4 mm and a trap entrance diameter of 25 mm. Five traps were baited, with manufactured marshmallow bait, and deployed along a transect for a maximum of 24 hours at each littoral station for a total of 30 traps. Traps were placed across a range of depths (0.5 m, 1.0 m, 1.5 m, 2.0 m, and 3.0 m) of the littoral zone (<3 m deep) using a Hummingbird portable depth sounder ("110 fishin' buddy").

The hoop nets measured 3.4 m in length with a 12-mm mesh size and an entrance ring diameter of 1.1 m. Hoop nets were deployed opportunistically in one of two ways: 1) with the opening parallel to shore and an attached seine net extending perpendicular to the shoreline (Figure 2.7); or 2) with the opening perpendicular to shore and a seine net attached to the wing extending to the shoreline. Hoop nets were set at each of the littoral stations, baited with sardines and left to soak for a maximum of 24 hours.

Figure 2.7 Photograph of a hoopnet set in the No Net Loss Lake littoral zone, Fort Hills Oil Sands Project, August 2018.



Gillnetting was conducted using multi-gang scientific nets with panel mesh sizes of 25 mm, 38 mm, 51 mm, 64 mm, 76 mm, 102 mm, and 127 mm; each of the seven panels was 7.6 m long by 2.4 m deep. Gillnets were set in the pelagic area of the lake and were left to soak for a maximum of two hours per set. One floating gillnet, at the surface of the lake, and one sinking gillnet, at a depth greater than three meters, were deployed during the program in an effort to sample the whole water column.

Boat electrofishing was conducted using a Smith-Root 2.5 GPP portable electrofisher with dual boom arrays and two dip-netters. One complete perimeter sweep was completed within the shallow area of the littoral zone as well as the perimeter of the island followed by six 100 m transects in the deeper portion of each of the littoral stations (Figure 2.6).

Seine netting utilized one 10-m juvenile stop-net (0.25" mesh size) deployed (i.e., pulled) three times at each littoral station with approximately 20 m distance between each sampling replicate (Figure 2.6).

Angling was conducted at two pelagic stations, two littoral stations (LZ3 and LZ4) and from the island in 2018 (Figure 2.6). Angling consisted of casting for 15 minutes per location using assorted fishing tackle.

All captured fish were identified to species, weighed with a digital tabletop scale (400 g ± 0.01 g), measured (±1 mm fork length), and examined for external abnormalities. All large-bodied fish greater than 150 mm in length received PIT tags to allow recapture data to be generated during future sampling events and track the movement of tagged fish. PIT tags were inserted into the ventral area of the abdominal cavity midway between the pectoral and pelvic fins using an MK10 syringe-style implanter. A Biomark 601 handheld reader was used to scan captured large-bodied fish for the presence of previously deployed PIT tags. Anal fin rays were collected from each northern pike for ageing analysis, using protocols described in MacKay et al. (1990); the minimum fork length of pike for collecting a non-lethal ageing structure was 150 mm. The fin rays were placed in scale envelopes to dry, and shipped to North/South Consultants (Winnipeg, MB) for age determination.

Outlet Channel and Creek A

Fish population monitoring on the outlet channel and Creek A was conducted concurrently with the fish habitat surveys on September 18, 2018, to assess fish utilization per mesohabitat unit of the outlet channel and fish passage throughout the system (i.e., from the Athabasca River through the outlet channel to the NNLL and from the NNLL into Creek A). Fish population monitoring was consistent with procedures outlined in the FiSH Committee Field Sampling Protocols Manual (Hatfield 2013).

Fishing units are also referred to as sampled mesohabitat units (SMUs) because they are positioned within a single mesohabitat type. SMU replicates were selected to provide data for the entire range of mesohabitat classes present in each survey reach. The length of each SMU was dependent on the size of the meshohabitat unit being sampled, but as a rule of thumb was no less than 10 m in length, and generally no more than 50 m.

The fish survey was conducted using single pass (full coverage) backpack electro-fishing (Smith Root LR-20B electrofisher) to collect a representative proportion of each fish present in an SMU. All fishing units sampled had a wetted width of less than <5 m and an average depth of <1 m. As such, one backpack electrofisher and one netter were used to sample the entire SMU length from bank-to-bank without bias towards specific areas.

All fish captured from each pass/station were held in separate aerated holding containers until the survey was completed. All captured fish were enumerated, weighed with a digital scale (±0.1 g), and measured for fork length (±1 mm). Stage of maturity was recorded when possible. All large-bodied fish with a fork length greater than 150 mm also received a PIT tag.

Remote PIT Tag Stations

Two PIT Tag stations (readers and antennae; IS1001 Standalone) were installed in the outlet channel in the summer of 2015. One antenna was installed at the outlet of NNLL (OC1) and the second installed near the confluence with the Athabasca River (OC3). The locations of the PIT Tag stations were selected to monitor fish passage through the system. The intent of the OC1 station is to monitor fish movement in and out of the lake, and the station at OC3 was deployed to monitor fish moving in and out of the outlet channel from the Athabasca River. The antennas only record fish that have been tagged with PIT tags.

The system began submitting real-time data on October 13, 2015 via cellular-based telemetry and operates year-round.

2.1.8.3 Fish Tissue

Muscle tissue from 24 northern pike, one burbot and three yellow perch that measured >150 mm fork length were sampled non-lethally for mercury and methylmercury analysis using a clean, unused 4-mm dermal biopsy punch (Acuderm Inc.). As specified in the FRL a maximum of five fish per 100 mm size class to a maximum of 30 samples per species were sampled, and individual fish with evidence of previous sampling were excluded from additional analysis of methylmercury in tissue.

Prior to sampling, a few scales were removed from the fish and the dermal punch was then positioned on the surface of the skin over the dorsal musculature. The punch was pushed into the dorsal musculature, using pressure and a twisting motion moderate enough to penetrate the muscle, but not to penetrate through to the fish cavity. Upon extraction, the punch was rotated in a twisting motion using slight angular pressure in order to assist in obtaining the muscle plug sample. The tissue plug was then blown through the hollow punch into a sterile, pre-labelled, pre-weighed (± 0.001 g) 4 mL externally-threaded cryovial. The wet weight of the plug was then recorded (± 0.001 g) for the calculation of total mercury concentration, and was placed immediately on dry ice in a cooler. After extraction of the punch, the void left in the fish was filled with a waterproof "bandage" sealant (Nexaband S/C, Topical Tissue Adhesive, Formulated Cyanoacrylate) in order to decrease the chance of infection.

All sampling equipment was rinsed using metals-free soap and distilled water, hexane, then acetone, and re-rinsed with deionized water after each fish to avoid cross contamination. Tissue samples were transported in a cooler on dry ice and held in the Hatfield freezer (Fort McMurray) before being shipped on dry ice to Flett Research (Winnipeg) for mercury analysis.

2.2 ANALYTICAL APPROACH AND DATA ANALYSIS

2.2.1 Surface Hydrology and Climate

During the 2018 WY, the NNLL hydrometric stations were visited in December, February, March, May, June, August, September, and October, for a total of eight field visits. The purpose of the hydrometric monitoring on NNLL was to assess:

- the hydrologic characteristics of the basin, which includes determining if year-round inflows and outflows to and from the lake occurred;
- if fish passage from NNLL to the Athabasca River was possible through the Outlet Channel; and
- the water level variation in NNLL and if a stable littoral zone is maintained.

The assessment was conducted using the field data collected at each of the four hydrometric stations, as well as the climate station, and from the manual measurements conducted during each of the eight field visits.

2.2.1.1 Data Analysis

In order to assess the NNLL hydrologic conditions in a regional context, comparisons with regional hydrometric and climate stations were performed. The closest publicly available hydrometric data set with a sufficient record length to provide meaningful long-term data is the WSC hydrometric station, 07DA008 – Muskeg River near Fort McKay, which is approximately 20 km south of NNLL. The 2018 WY 07DA008 hydrograph, as well as historical discharge statistics, were used to provide regional context.

The hydrologic conditions of NNLL were assessed using the NNLL lake level (LL1), the inflow (IC1), and outflow (OC1 and OC2). The NNLL water level was assessed by comparing the lake level variations to previous years' records, the precipitation from the NNLL climate station as well as the design criteria set out by Golder (2006). The discharge timing and magnitudes for IC1, OC1, and OC2 were compared relative to one another and the lake outlet channel design discharge. Historical IC1, OC1 and OC2 flows were graphed and evaluated to determine whether consistent flow was present in the outlet channel on a year-round basis.

A volumetric water balance was calculated to quantify the water inputs and losses from NNLL. This allowed the hydrologic functionality of the lake to be assessed and identifies potential changes over time. The water balance was calculated on a daily basis using the equation described in Hood (2006):

$$IG - OG = \Delta V/\Delta t - P + E - Is + Os$$

All water balance components and data sources are described in Table 2.7.

Table 2.7 Components and data sources used to calculate the water balance for the No Net Loss Lake, Fort Hills Oil Sands Project, 2018 WY.

Component	Data Source	Location	Operator
IG-OG – Residual (Groundwater)	Calculated	N/A	N/A
ΔV/Δt – Lake storage change	LL1 Water Level Station	NNLL	SEOI (May 2014-)
P – Precipitation	NNLL Climate Station	NNLL	SEOI (May 2014-)
E – Evaporation	Morton Method evaporation data (AESRD, 2013)[1]	NNLL	SEOI (May 2014-)
Is – Inflow (surface water)[2]	IC1 Hydrometric Station	NNLL	SEOI (May 2014-)
Os – Outflow (surface water)[2]	OC1 Hydrometric Station	NNLL	SEOI (May 2014-)

[1] Evaporation data were derived by averaging monthly Morton Method values from 2017 for NNLL and disaggregating monthly values to daily by dividing by the number of days in each month.

[2] Missing data points were filled with interpolated values for the purpose of calculating the water balance.

The residual component of the water balance reflects the water that is not accounted for by the known measured or calculated components and is generally accepted to be the groundwater component of the water balance. A positive residual value indicates the lake gained water from groundwater inputs (i.e., IG), and a negative residual value represents water losses to groundwater (i.e., OG).

2.2.1.2 Hydrometric Data Production Procedures

Production of the NNLL hydrometric data was completed using procedures outlined in BC MOE (2009) and WSC (2001). In general, corrections to water level data were applied where differences with manually surveyed water levels exceeded 0.004 m. Manual discharge measurements and concurrent water levels were compared on a plot of stage versus discharge, to develop a stage-discharge relationship (SDR). Following the development of an SDR, a discharge time series was calculated using the continuous stage (water level) record and the SDR using the following equation:

$$X = C * (Y - a)^\wedge b$$

where X is the calculated discharge (in m^3/s), C is a rating curve constant, Y is the manually measured stage (m), a is the rating curve offset (or stage at zero flow), and b is the rating curve slope.

During the computation of a calculated, continuous discharge time series, corrections were applied to the available SDR model to ensure that the calculated discharges fell within 5% of the manual discharge measurements. This was accomplished by shifting the SDR to the available manual measurements. Shift corrections help to account for streambed scour or deposition processes and backwater effects on the SDR. It should be noted that the SDR's derived for the stations in the NNLL monitoring program utilize a relatively short period of record and are considered preliminary. These SDR's will be revised and refined with the collection of additional discharge measurements.

2.2.2 Water Quality

2.2.2.1 In Situ Water Quality

Monthly in situ water quality depth profiles were presented graphically and in tabular format for the NNLL to assess seasonal lake stratification across the water column and seasons.

Data from the light penetration and water temperature loggers were plotted into depth-integrated time-series graphs using SigmaPlot 12.5.

Continuous time trend graphs of the daily in situ water quality measurements were presented in graphical format and screened against relevant guidelines where possible.

2.2.2.2 Analytical Water Quality

Water quality results were presented in tabular format, compared across seasons, and screened against relevant guidelines for the protection of aquatic life (GoA 2018). Key water quality variables were presented in graphical format across seasons and years for the NNLL, the outlet channel and Creek A.

A Piper plot diagram was also used to illustrate the ion concentrations in the NNLL and outlet channel.

2.2.3 Sublethal Toxicity Testing

2.2.3.1 Water Toxicity

Results of the 72-hour growth inhibition test using a freshwater alga were presented in graphical format to show mean cell count across the range of lake water concentrations. Results of the reproduction and survival test using a freshwater invertebrate were presented in graphical format to show the mean number of neonates produced and percent mortality across the range of lake water concentrations. Results of the larval growth and survival test using fathead minnow were presented graphically showing biomass (mg/fish) and percent mortality across the range of lake water concentrations. Inhibitory concentrations (IC25 and IC50) and/or lethal concentrations (LC25 and LC50) were identified for each test.

2.2.3.2 Sediment Toxicity

Results of the static test for survival and growth in sediment using a freshwater amphipod and freshwater midge were presented in graphical and tabular formats showing the percent survival compared against laboratory controls.

2.2.4 Plankton Communities

The following indices were used to assess phytoplankton and zooplankton communities of NNLL:

- Abundance (No./m^2) – Reflects the density of organisms in the lake. Nutrient enriched systems often support greater numbers of species per unit area, which can be measured by an increase in abundance;
- Taxa richness – The number of distinct taxa present in a sample or per unit area. Systems with more taxa are generally considered to be of higher environmental quality. Moderate nutrient enrichment generally increases taxa richness, while excessive enrichment may affect water oxygenation, resulting in a reduction in richness. Toxic conditions in water, will also affect taxa richness and composition;
- Simpson's diversity index (D), where

  $$D = 1 - \sum (p_i)^2$$

  and p_i is the proportion that taxon i contributes to the total number of invertebrates in a sample; and
- Evenness – measure of "diversity" that also incorporates abundance. Evenness is an alternative measure of diversity that is standardized against the "maximum possible" diversity (defined as a community with equal numbers of all taxa present), where

  $$\text{Evenness} = \frac{D}{D_{max}}$$

  $$D_{max} = 1 - \left(\frac{1}{S}\right)$$

Diversity is lower when stations are dominated by a few taxa. High diversity and evenness are considered indicators of favorable habitat conditions.

All indices were presented in tabular and graphical format. Percent abundance and biomass (mg/m^3) of each taxa group were also presented graphically.

2.2.5 Benthic Invertebrate Communities and Sediment Quality

2.2.5.1 Benthic Invertebrate Communities

The following indices, which are similar to the plankton indices, were used to assess benthic invertebrate communities of the NNLL:

- Abundance ($No./m^2$);
- Taxa richness (number of taxa);
- Simpson's diversity (see equation in Section 2.2.4);
- Evenness (see equation in Section 2.2.4); and
- Percent ETO (percent of fauna as Ephemeroptera, Tricoptera and Odonata) – A measure of the percentage of all benthic invertebrates in a sample that belong to the more sensitive groups of mayflies, caddisflies and dragonflies/damselflies. The presence of more sensitive species is an indicator of a healthy aquatic system. This measure is generally more applicable to lake/pond habitats than the measure of percent EPT (Ephemeroptera, Plecoptera, and Tricoptera), used for erosional stream habitats.

With the exception of percent ETO, these are the same assessment metrics identified in the RAMP Design and Rationale Document (RAMP 2009), and which continue to be used for ongoing regional oil sands monitoring under the JOSMP (JOSMP 2016). Using the same assessment metrics for the NNLL allows comparisons to be made with long-term regional datasets (e.g., McClelland Lake, Shipyard Lake, Isadore's Lake, and Kearl Lake).

All indices were presented in tabular and graphical format. Proportions of major taxonomic groups and functional feeding groups in the benthic invertebrate community were presented graphically.

2.2.5.2 Sediment Quality

Key sediment quality variables, outlined in Section 1.3.1 and relevant to oil sands development, were presented in tabular format and screened against sediment quality guidelines for the protection of aquatic life (GoA 2018) and compared to regional lakes (e.g., McClelland Lake, Shipyard Lake, Isadore's Lake, and Kearl Lake).

2.2.6 Vegetation Communities

2.2.6.1 Macrophyte Communities

Summer marcophyte density was presented in tabular format. Percent cover of each species in 1 m^2 quadrats were presented to assess changes in community composition across depths of the littoral zone. Overall macrophyte cover in the littoral zone for validation of fish habitat suitability when calculating HU in the NNLL was determined by averaging percent cover across the six macrophyte transects.

2.2.6.2 Riparian Vegetation

Percentage of overhead cover per plot for each transect was presented is tabular format.

2.2.7 Fish Habitat

Fish habitat was assigned measures of quality based on the Habitat Evaluation Procedures (HEP) approach developed by the Unites States Fish and Wildlife Service (USFWS 1980). Habitat quality was defined using HSI, which rank the importance of available habitat for specific species and life stages of fish (Golder 2008) and are an integral part of the HEP approach (USFWS 1980). The HSI for a given species and area represents a conceptual model that describes how measurable habitat variables relate to the suitability of a discrete habitat unit, scaled from 0 to 1 (i.e., unsuitable to optimal). Typically, a wide variety of habitat variables are used in the model, with each represented by a single suitability index (SI), which may be life stage-specific. The SIs are linked by functions that reflect relationships among variables, but often variables are assumed to be independent. Together the SIs makes up a single HSI for a species.

HSI models were applied to assess overall habitat suitability for fish populations in the NNLL and the outlet channel. HSI models outlined in Golder (2008) were applied to all fish species identified for inclusion to the NNLL (Golder 2006) to calculate habitat suitability values. Suitability index (SI) values were calculated for each fish species, using habitat data collected across all four seasons. SI values were calculated as follows:

1. Each habitat variable in the HSI model was assigned a ranking between 0 and 1 (0 = none; >0 to 0.3 = below average; >0.3 to 0.6 = average; >0.6 to 0.9 = above average; and >0.9 to 1.0 = excellent).
2. If the habitat variable had multiple categories with multiple rankings, a weighted average was used to determine overall ranking for each habitat variable.
3. For most small-bodied fish species the SI was determined by the lowest ranking habitat variable in the HSI model; for sucker species and sportfish, SI determination was species-specific (Golder 2008).

HU per species were then calculated by multiplying the area of the NNLL and outlet channel by the SI value for each species.

2.2.8 Fish Populations

Catch-per-unit-effort (CPUE), grams per-unit-effort (GPUE) and percent composition was calculated and presented in tabular format for each species by location and gear type. CPUE was used to index fish abundance and GPUE was used to index fish biomass. CPUE calculations by gear type were summarized in Table 2.8. The number of fish captured, tagged and aged was presented in tabular format.

Table 2.8 Catch-per-unit-effort calculations per gear type in No Net Loss Lake, Fort Hills Oils Sands Project, 2018.

Gear type	Catch-per-unit-effort
Minnow traps	Number of fish per minnow-trap hour
Hoop net	Number of fish per hoop-net hour
Gillnets	Number of fish per gillnet minute
Beach Seine	Number of fish per pull
Electrofishing	Number of fish per 100 electrofishing seconds
Angling	Number of fish per 15 angling minutes

2.2.8.1 Fish Tissue

Results of total mercury concentrations in fish tissue were presented with age data in tabular format and screened against Health Canada guidelines for general fish consumption (0.5 mg/kg; Health Canada 2007) and subsistence fish consumption (0.2 mg/kg; Health and Welfare Canada 1979). Mercury concentrations in fish tissue collected from the NNLL were standardized to size and compared to mercury concentrations in fish collected from other lakes in the region by JOSMP. Regional comparisons of mercury concentrations in fish tissue were presented graphically.

2.3 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) procedures and results are provided in Appendix A5.

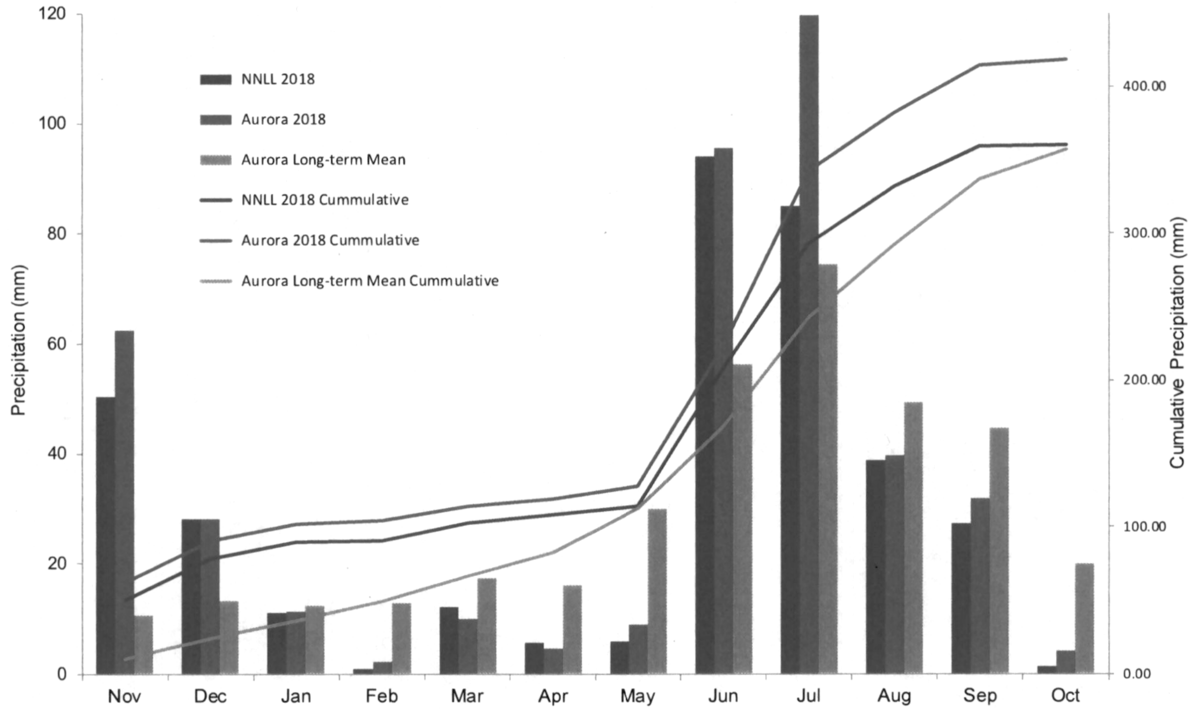
3.0 RESULTS AND DISCUSSION

3.1 SURFACE HYDROLOGY AND CLIMATE

3.1.1 Historical Precipitation Conditions

To provide a historical perspective, precipitation from a regional climate station in the 2018 WY was compared to long-term historical data. The closest regional climate station with a long historical record is the Aurora climate station (Aurora), part of the AEP network. In the 2018 WY, precipitation at C1 was 15% higher than the long-term average at the Aurora station (2004-2017; Figure 3.1). The 2018 WY precipitation at NNLL was 1.0% higher than the Aurora long-term average, and 16.1% lower than the 2018 WY. The 2018 NNLL and Aurora months of January through May and August through October tended to be drier than the long-term average with November, December, June and July exceeding the long-term average and accounting for almost 75% of the annual precipitation.

Figure 3.1 Monthly and cumulative precipitation at the NNLL and Aurora climate stations in the 2018 WY relative to historic precipitation.



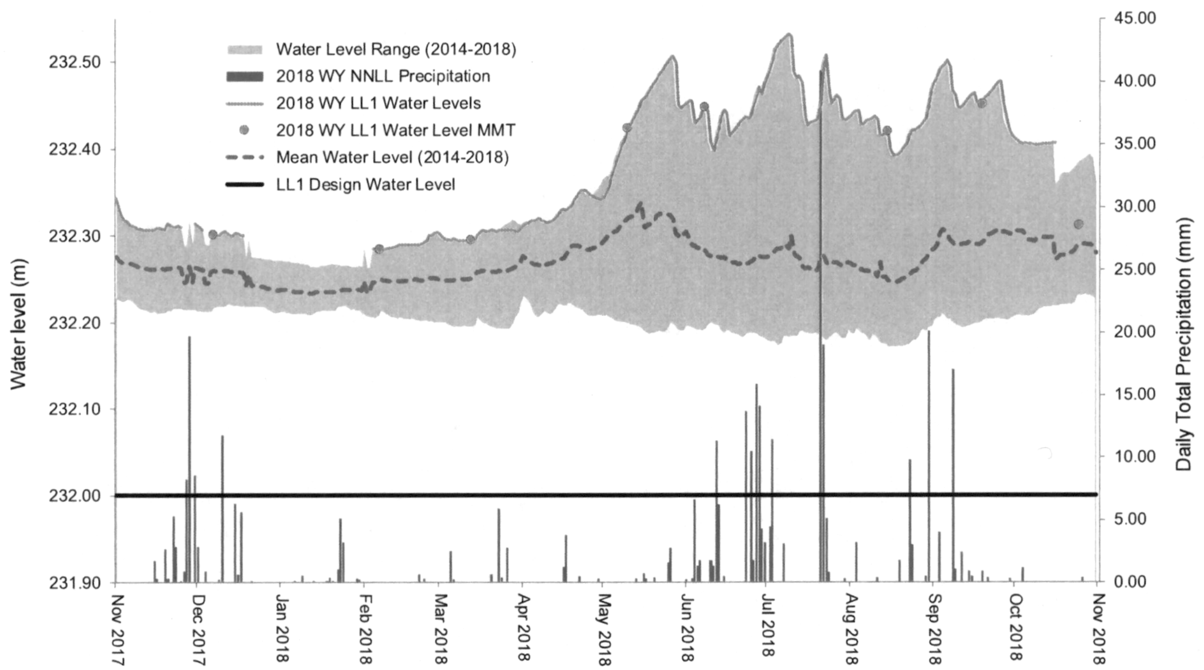
Note: The long-term Aurora record consists of data from 2004 to 2017 (only years with complete records were analyzed).

3.1.2 No Net Loss Lake

3.1.2.1 Lake Levels

The lake level of NNLL during the 2018 WY exhibited a greater range than in previous years (Figure 3.2). Maximum and minimum lake levels at NNLL station LL1 were 232.532 m and 232.284 m, respectively, and remained above the historical lake mean water level and designed operational water level of 232.0 m (Golder 2006) for the duration of the 2018 WY. The average lake level in the 2018 WY was greater than previously recorded, except for two brief periods between late-March and early-May 2018.

Figure 3.2 Water level of No Net Loss Lake in the 2018 water year compared to the historical range (2014-2018) and daily precipitation measured in 2018.



[1] NNLL Climate Station precipitation data presented from November 1, 2017 to October 31, 2018.

[2] NNLL Climate Station precipitation data estimated from December 7-18, 2017 and February 3-8, 2018 due to faulty power supply.

[3] LL1 water level data gaps from November 2017 through to February 2018 due to faulty power supply.

[4] LL1 pressure transducer removed for calibration on October 16, 2018.

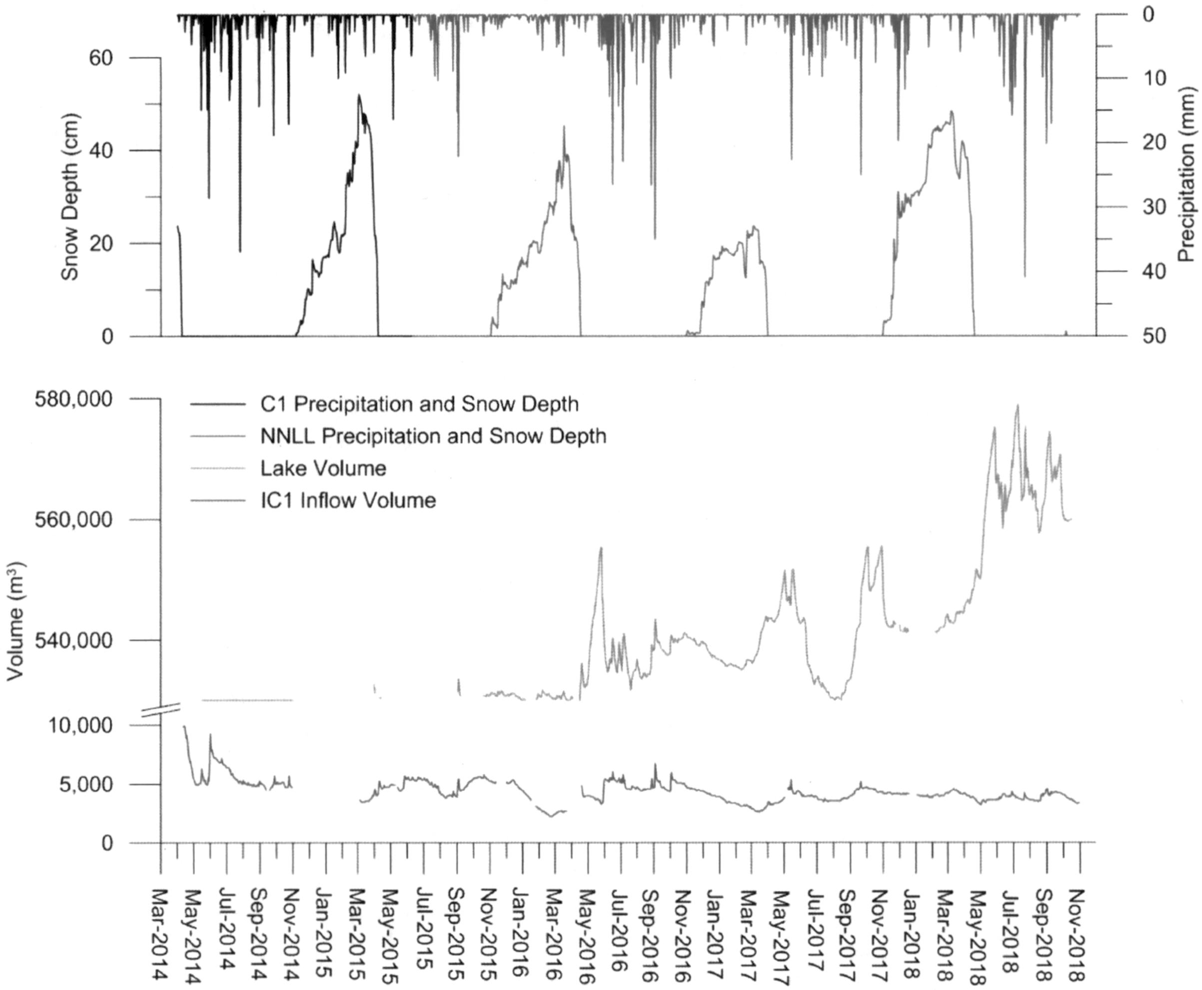
Variability in lake levels was closely related to specific precipitation events, such as the early and late June, late July, late August and early September large rainfall events as presented in Figure 3.2. There was also a prominent rise in lake level beginning May 1st which coincides with freshet and the initial beaver activity identified at the lake outlet. Ongoing beaver activity (i.e., dam construction at the lake outlet; see Section 3.6.1.1 and Figure 3.3) from May to September contributed to lake water levels that were higher than previous years (Figure 3.4).

Figure 3.3 Photo of beaver dam at NNLL outlet looking upstream on July 18, 2018.



Pumping into NNLL during construction along the toe of earthfill berm occurred in March and April but did not contribute significantly to the rise in lake level during that time. In general, hydrologic conditions and beaver activity in 2018 resulted in the NNLL water level elevation to be higher than previous years and between 0.284 m and 0.532 m above the design operational water level as seen in Figure 3.2.

Figure 3.4 Continuous No Net Loss Lake volume and precipitation (2014-2018).



Note: Based on a lake volume of 530,056 m^3 and lake area of 152,480 m^2 on July 10, 2014. Assumes constant lake area.

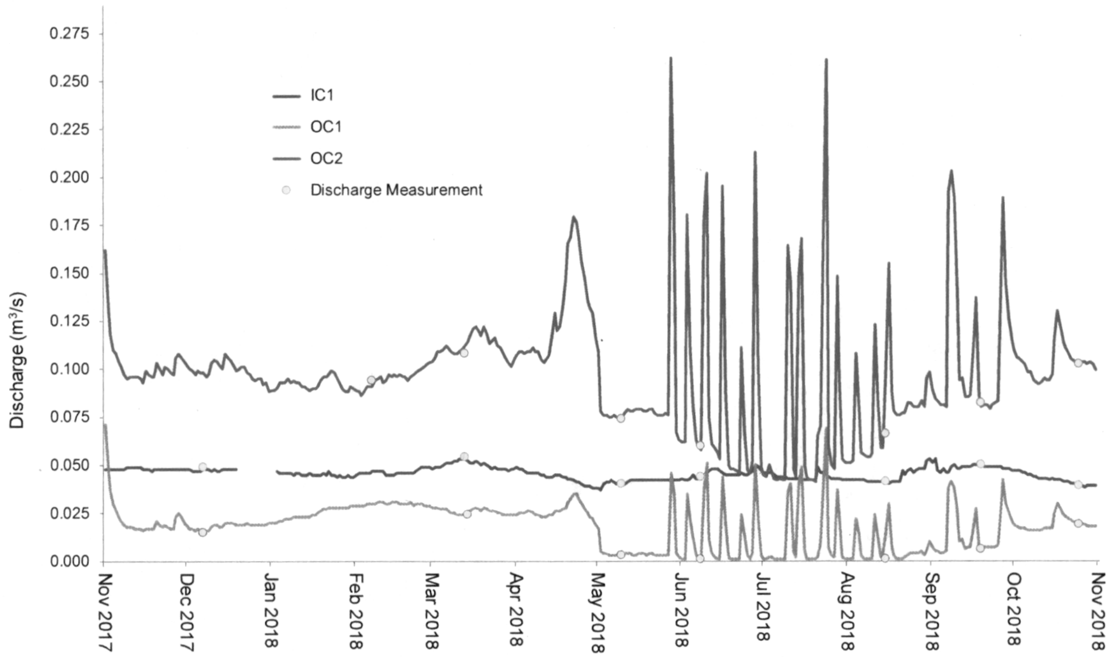
The maximum variation in lake level over the 2018 WY was 0.248 m. The littoral zone (defined as ≤3 m deep) accounts for approximately 40% of the NNLL of which 8.3% was exposed to lake level fluctuation compared to 5.6% in 2017 and 6.1% in 2016. The increase in littoral zone area exposed to lake level fluctuation in 2018 is mainly a result of beaver dam construction at the lake outlet.

3.1.2.2 Lake Inflows and Outflows

Discharge hydrographs for the lake inlet (station IC1, Creek A), the lake outlet (station OC1) and a downstream outlet channel (station OC2) for the 2018 WY are presented in Figure 3.5, and for the historical period of record in Figure 3.6.

Similar to previous water years, the discharge of Creek A at station IC1 was consistently higher than the lake outlet flow recorded at station OC1, with the exception of numerous spikes at station OC1 coinciding with beaver dam removal events.

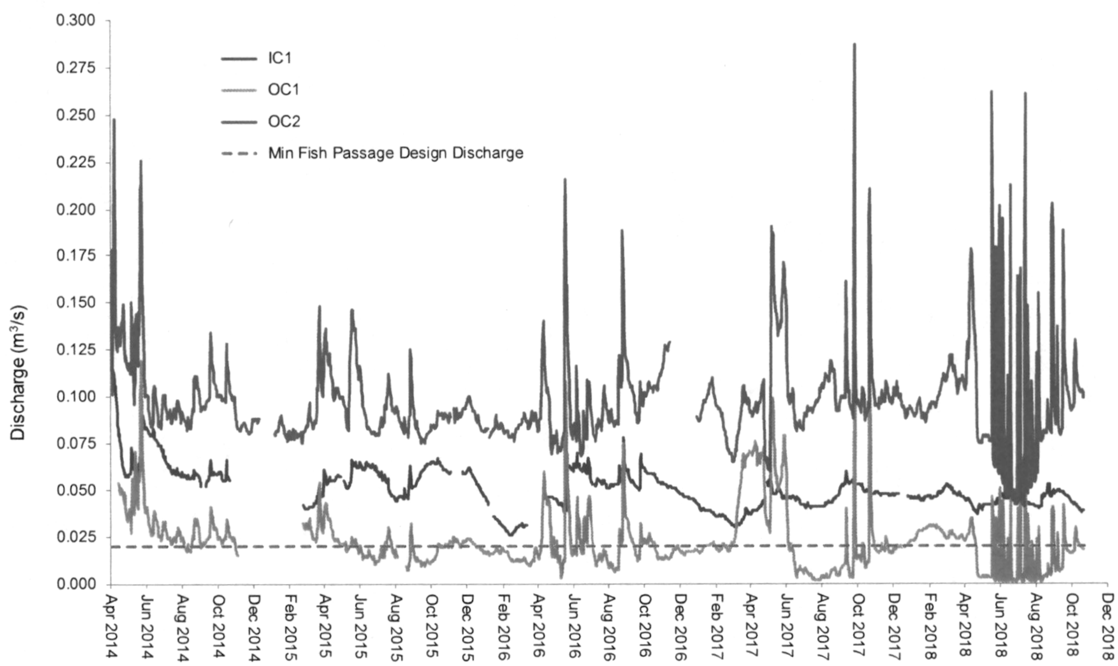
Figure 3.5 **Discharge hydrographs measured at stations IC1 (Creek A), OC1 (the Outlet), and OC2 (Outlet Channel), Fort Hills Oils Sands Project, during the 2018 WY.**



[1] IC1 data gaps from December 19, 2017 to January 6, 2018 due to faulty logger.

[2] Multiple discharge spikes from late May onwards at both OC1 and OC2 due to beaver dam removals at NNLL outlet above OC1.

Figure 3.6 **Discharge hydrographs measured at stations IC1 (Creek A), OC1 (the Outlet), and OC2 (Outlet Channel) from 2014 to 2018, Fort Hills Oils Sands Project.**



Initial beaver dam construction in early May effectively raised the level of the NNLL outlet control resulting in a prolonged decrease in discharge at both station OC1 and station OC2. Following the initial dam removal on May 28th, the dam was rebuilt by beavers and removed by Fort Hills staff a total of sixteen times. Not until the beavers were removed on September 28th did the discharge return to historical norms.

Mean annual discharge (MAD) at station OC2 was 5.4 times greater than the MAD recorded at station OC1 during the 2018 WY. This increase in flow occurs over a short distance of approximately 300 m and is derived almost entirely from groundwater flowing to a ditch along the road-cut slope that enters the outlet channel between stations OC1 and OC2.

3.1.2.3 Water Balance of NNLL

Based on the monthly water balance for the NNLL (Table 3.1), it is evident that the water balance is largely dominated by stream inflows (IC1), stream outflows (OC1), and by a calculated residual, which is assumed to represent groundwater influence. Pumping estimates from the NNLL berm toe drain into NNLL from February 23rd to April 22nd were included in the calculation of the residual flow in the monthly water balance. Lake storage change (i.e., rises and drops in lake water levels), precipitation, and evaporation, when combined, made up a relatively small portion (7.2%) of the NNLL water balance.

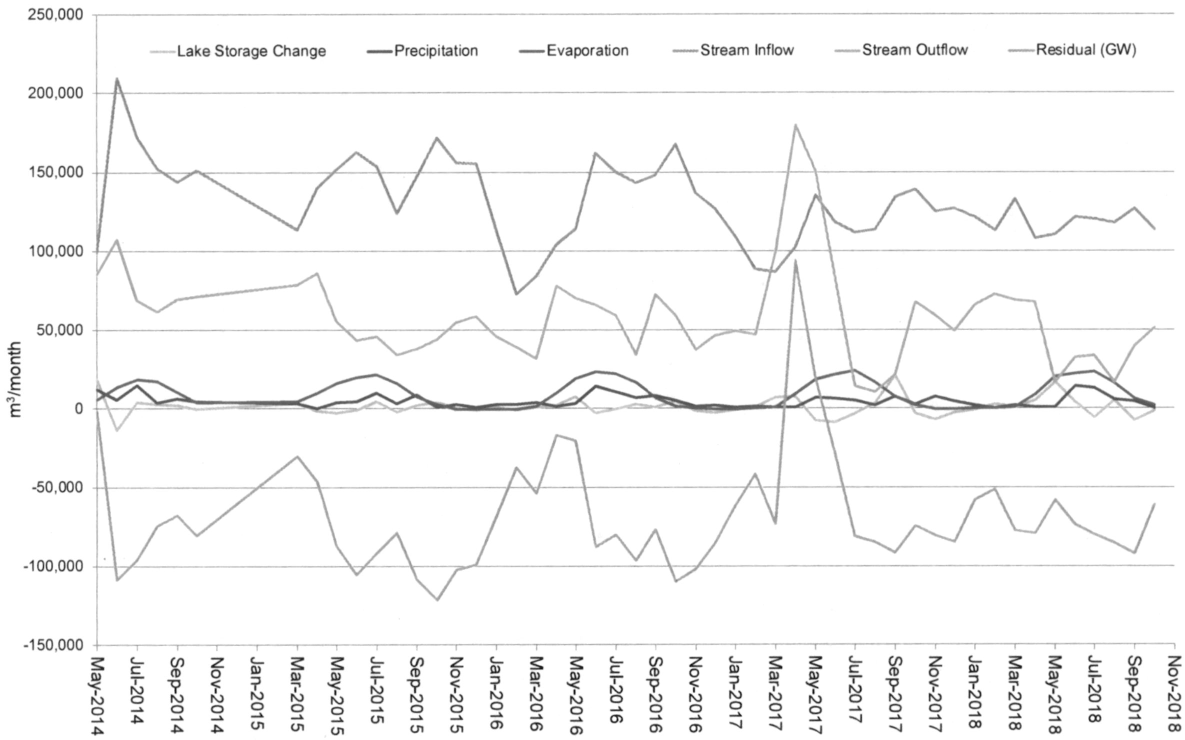
Table 3.1 Monthly water balance results for No Net Loss Lake, Fort Hills Oils Sands Project, 2018.

Month	Lake Storage Change (m^3/month)	Precipitation NNLL Climate (m^3/month)	Evaporation Morton (m^3/month)	Stream Inflow IC1 (m^3/month)	Stream Outflow OC1 (m^3/month)	Residual (GW) (m^3/month)
November	-7,363	7,728	-243	124,848	59,184	-80,998
December	-3,000	4,303	-694	126,403	49,334	-85,066
January	-1,106	1,701	-34	121,306	66,010	-58,137
February	2,572	133	-60	112,579	72,490	-37,711
March	614	1,875	933	133,920	68,947	-65,301
April	5,216	873	8,882	113,184	67,910	-32,049
May	16,567	907	19,992	110,419	16,762	-58,005
June	3,682	14,409	22,179	117,936	32,400	-74,084
July	-5,983	13,011	23,090	117,331	33,437	-79,799
August	5,062	5,926	16,127	117,072	16,416	-85,393
September	-7,977	4,185	6,395	126,317	39,571	-92,513
October	-1,381	225	2,024	113,011	51,235	-61,358

The water balance demonstrated that surface water inputs to NNLL exceeded surface water losses for every month in the 2018 WY. This result suggests that residual water was lost to groundwater throughout the 2018 WY. Residuals from the water balance accounted for 71% to 46% of the lake inputs. The period of record (2014 to 2018) demonstrated losses to groundwater generally decreased from the beginning of the WY to April, then increased to the end of the WY. This yearly pattern can be observed in the results of the historical monthly water balance (Figure 3.7) and the 2018 WY continues this pattern. The one exception to this pattern occurred in the 2017 WY when there was a net input into NNLL during April and May possibly due in part by construction activities that discharged water into the lake in spring.

Losses to groundwater continue to account for a substantial proportion of the NNLL water balance (Figure 3.7). However, the lake levels continued to remain above the operational water level (Figure 3.2) outlined in Golder (2006).

Figure 3.7 Historical (2014–2018) monthly water balance results for No Net Loss Lake, Fort Hills Oils Sands Project, 2018.



[1] Water balance gap from October 2014 to March 2015 due to unavailable stream flow data.

Similar to the 2017 WY, hydrologic monitoring results indicated that the NNLL water level was higher than previous years and displayed minimal fluctuation except for the period between mid-May to mid-September of 2018 as a result of beaver activity. Evidence of shoreline erosion or disturbance to the littoral zone was not observed, indicating that the littoral zone of the NNLL was stable during the open-water season. The water level of the lake was above the Design Water Level of the outlet channel for the entire water year (November 1 to October 31), though it was kept artificially high from May to October due to recurring beaver dam construction and removal. Consequently, the overall discharge at stations OC1 and OC2 was lower during this time. As a result of groundwater input above station OC2 (i.e., access road ditch), discharge at station OC2 remained above the minimum fish passage design discharge for the entire water year. Discharge at station OC1 dropped below the minimum fish passage design discharge frequently in May to October due to recurring beaver dam construction and removal.

The 2018 NNLL water balance demonstrated that surface water inputs to NNLL exceeded surface water losses for every month calculated in the 2018 WY suggesting that residual water is lost to groundwater for all months in the 2018 WY. This result is consistent with previous WY's with the exception of the 2017 WY when surface water losses exceeded surface water inputs during April and May, possibly due in part by construction activities that discharged water into the lake.

3.2 WATER QUALITY

3.2.1 In-situ Water Quality

3.2.1.1 No Net Loss Lake

Water temperature of No Net Loss Lake was monitored from mid-May to mid-October 2018 using Hobo loggers deployed at one-metre depth intervals at the deepest part of the lake (Figure 3.8). Thermal stratification was not observed in the NNLL in 2018, likely a result of groundwater input from Creek A (Figure 3.9).

Cumulative daily totals of light penetration measured at one-metre depth intervals at the deepest portion of NNLL (PZ1) are presented in Figure 3.10. As expected, light intensity decreased with depth and varied seasonally; however, water clarity and light penetration is higher than what is typical for other lakes in the region, likely a result of the constant groundwater input. In August, light intensity decreased near the lake surface (to 2 m deep) and at depths below 3 m, which is likely a result of an increase in phytoplankton production. This is further supported by the peak in chlorophyll *a* in August (see Figure 3.15). Light penetration determines the extent of the euphotic zone, the area of the lake where light-driven primary production is expected to occur (Wetzel 2001).

In 2018, seasonal in situ water quality depth profiles were measured in the NNLL (Figure 3.9 and Table 3.2). DO was fairly similar across depths and seasons; however, consistent with previous years DO decreased with increasing depth in March (Figure 3.9), but remained above guidelines for the protection of freshwater aquatic life (GoA 2018) to a depth of four metres (Table 3.2), indicating that suitable overwintering habitat for fish was being provided by the NNLL. With the exception of 2016 concentrations of DO have remained above guidelines to a depth of four metres across all years of the monitoring program (Table 3.3). Concentrations of pH remained similar across the water column and seasons with the exception of March where a gradual decrease with depth was observed. Specific conductance showed little variation across seasons with March and May being slightly elevated compared to other seasons. A gradual increase in specific conductance with increasing depth was observed in March and July.

Continuous measurements of temperature, specific conductance, pH, turbidity, chlorophyll *a*, and DO were collected in NNLL from May 11 to October 15 (Figure 3.11 to Figure 3.16). Continuous water quality data are provided in Appendix A2.

Across the open-water period, water temperature of NNLL correlated with ambient air temperature with the highest water and air temperatures recorded in June (23.2 °C and 26.6 °C, respectively) and the coldest temperature being recorded in late October at the time the sonde was removed (Figure 3.11). Water temperature in 2018 was similar to previous years (Figure 3.11). Conductivity exhibited a gradual decrease from 311 µs/cm on May 24 to 205 µs/cm on August 9 and then a gradual increase to 250 µs/cm on October 15 (Figure 3.12) and was similar to values observed in 2016 and 2017. pH exhibited a gradual increase from 7.9 on May 11 to 8.8 on August 9 and then a gradual decrease to 8.4 on October 15. All measurements of pH were within the water quality guideline for the protection of freshwater aquatic life (6.5 to 9.0, GoA 2018; Figure 3.13).

Turbidity in the NNLL (measured in the pelagic zone) is low (Figure 3.14) in comparison to other lakes in the region (e.g., Shipyard Lake, McClelland Lake, Isadore's Lake; JOSMP 2016 and Hatfield 2016). Turbidity was highest on May 11 (1.53 NTU) following the spring melt. Turbidity in 2018 was within historical ranges.

Daily average concentrations of chlorophyll *a* fluctuated between 4.3 µg/L and 0.5 µg/L during the open-water period and experienced variation similar to what was observed previous years. Although not as pronounced as in 2016, a peak in chlorophyll *a* was observed in August 2018, which aligns with the lower light intensity levels measured in the pelagic zone in August 2018 (Figure 3.15).

DO in 2018, remained stable during the open-water season (i.e., fluctuated between 9.6 mg/L and 13.8 mg/L) and within the guideline for the protection of freshwater aquatic life (i.e., 6.5 mg/L; GoA 2018). DO concentrations in 2018 were similar to 2017; however, exhibited higher concentrations in October (Figure 3.16).

Figure 3.8 Daily average water temperature in No Net Loss Lake, collected at one-metre intervals from the lake surface to bottom, May to October 2018, Fort Hills Oil Sands Project.

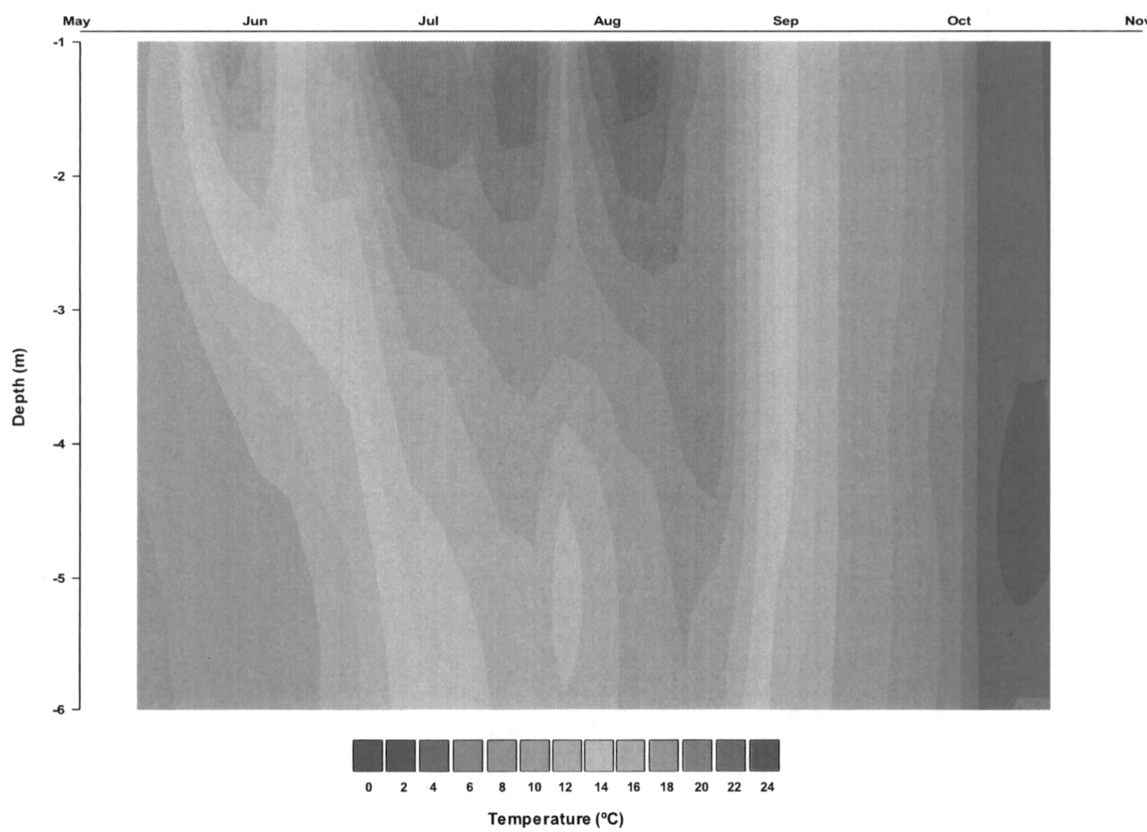
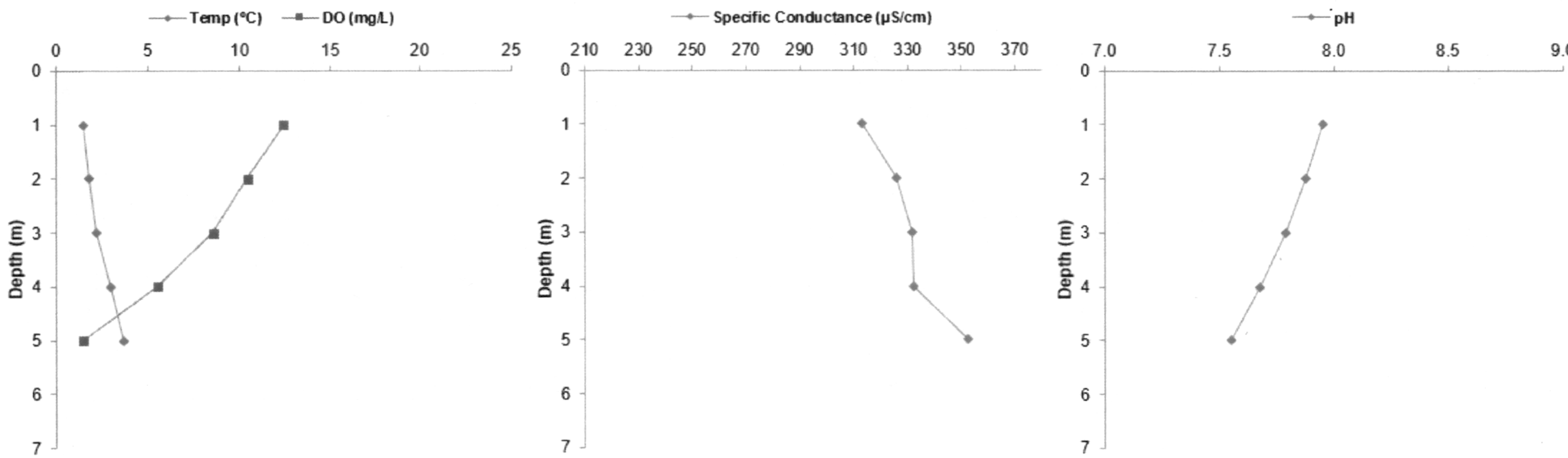


Figure 3.9 **Seasonal depth profiles of temperature, pH, dissolved oxygen, and specific conductance in No Net Loss Lake, Fort Hills Oil Sands Project, 2018 WY.**

March



May

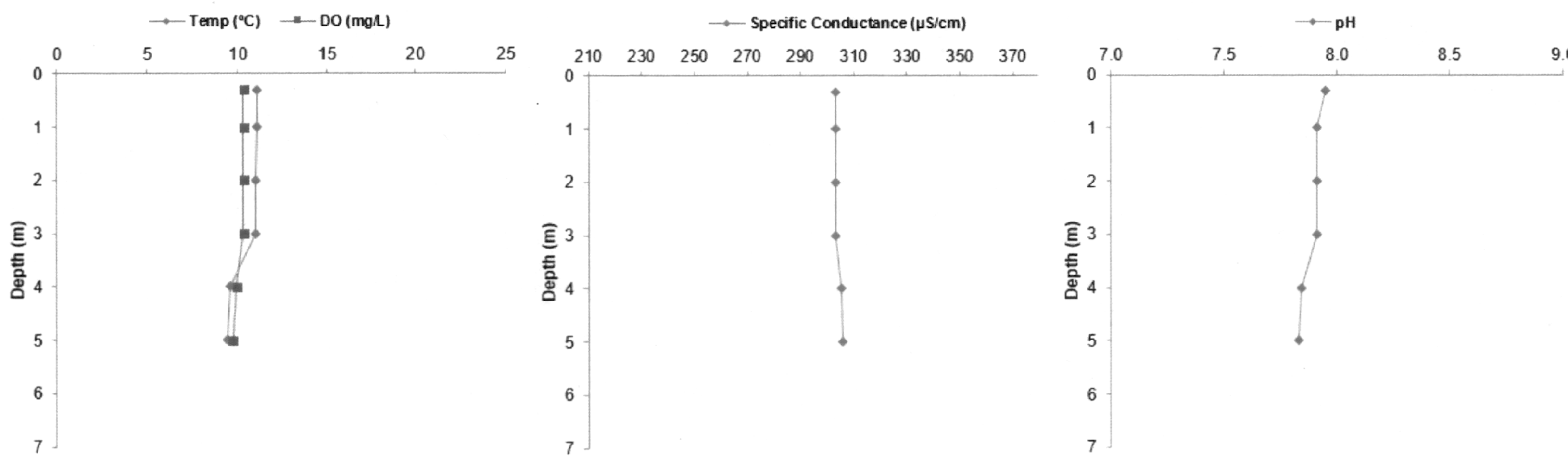
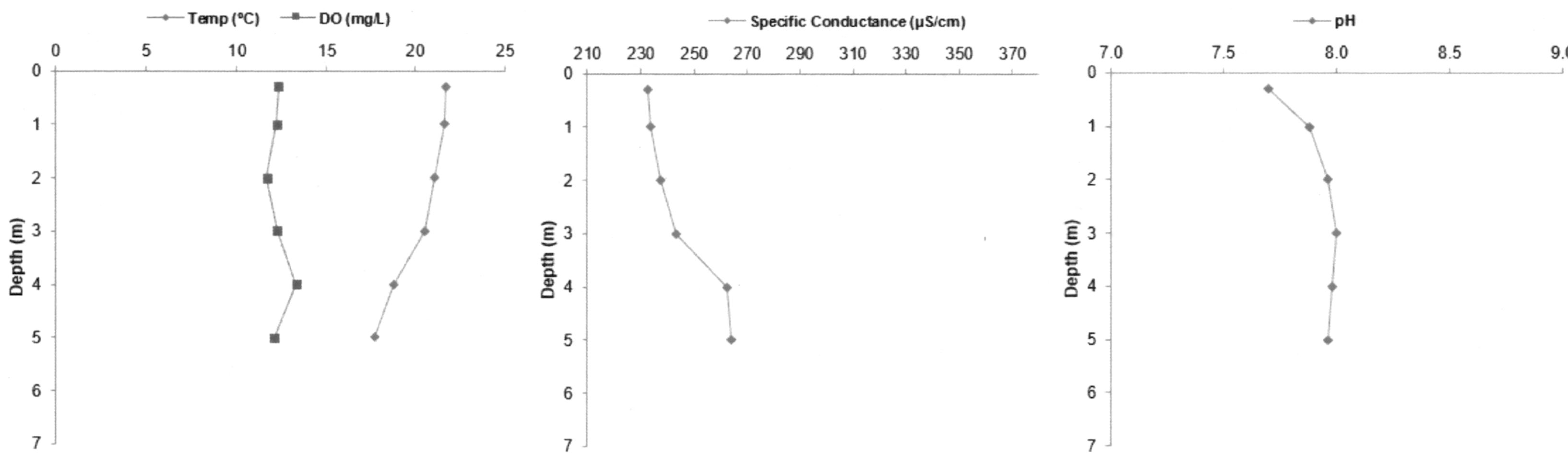


Figure 3.9 (Cont'd.)

July



August

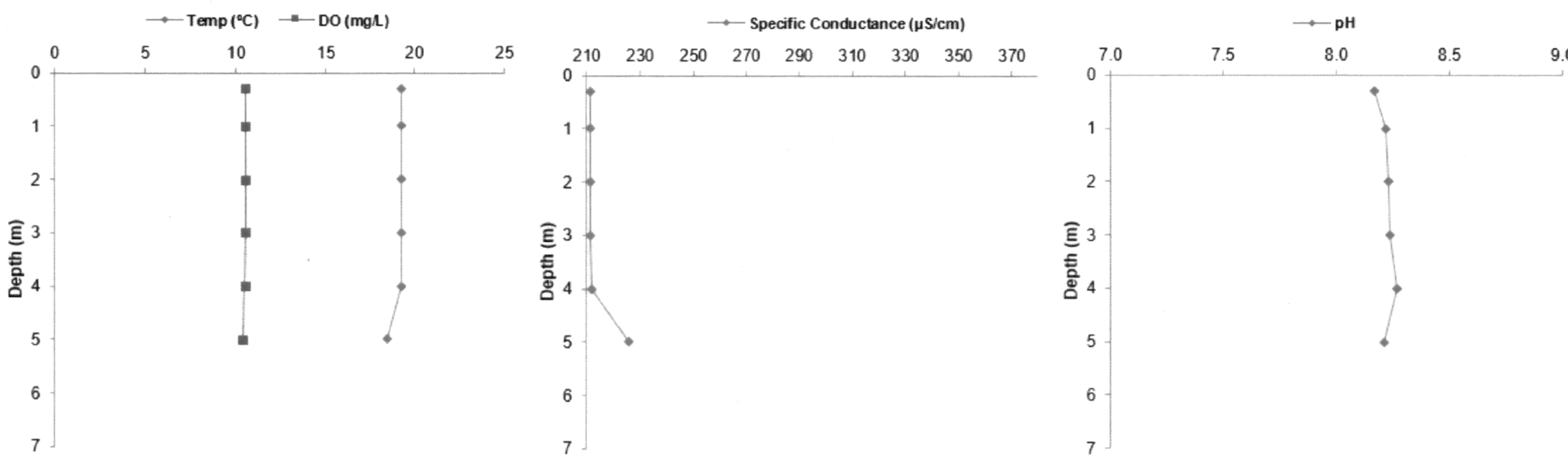


Figure 3.9 (Cont'd.)

September

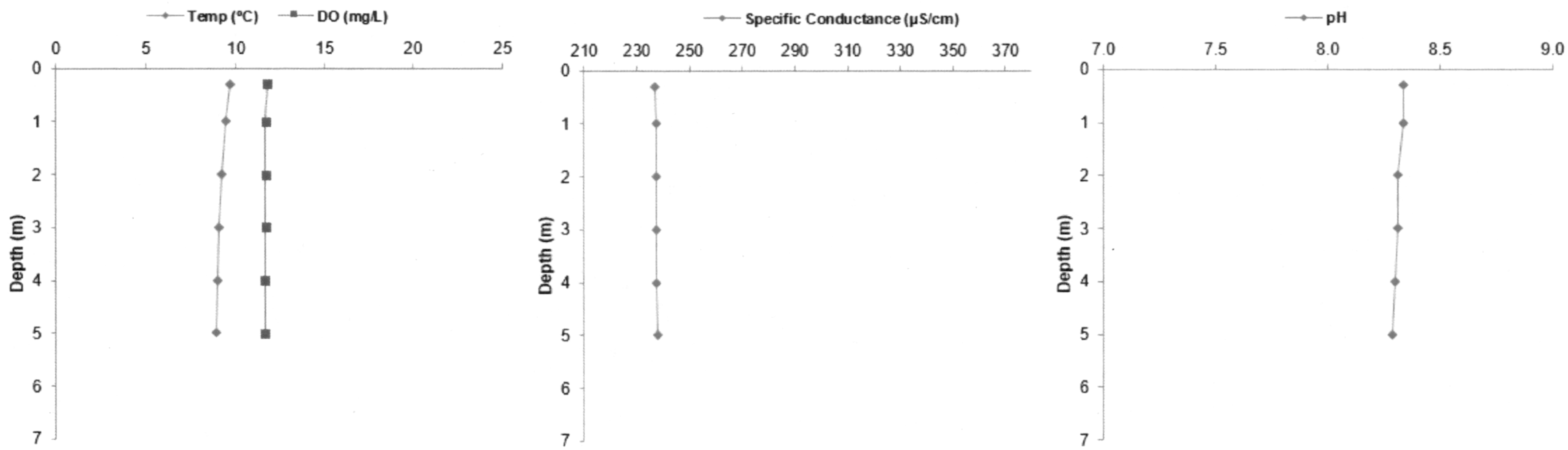


Figure 3.10 Daily cumulative light infiltration in No Net Loss Lake, collected at one-metre intervals across the depth profile, May to October 2018, Fort Hills Oil Sands Project.

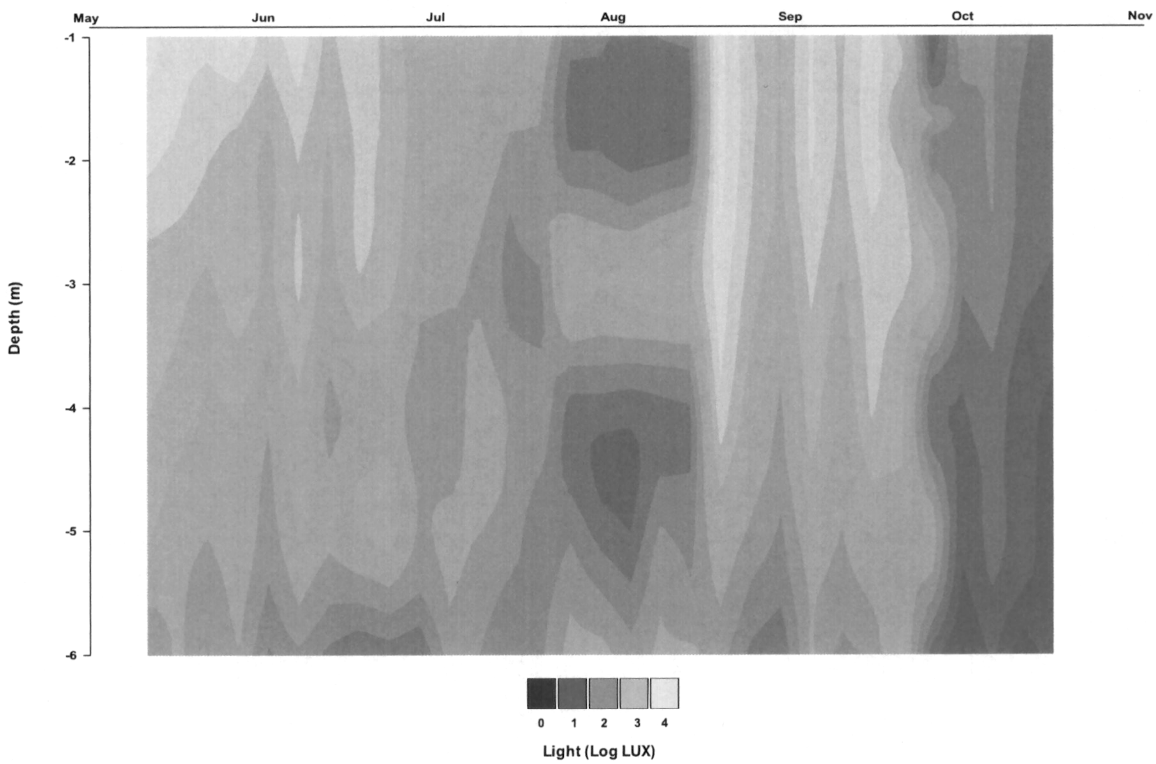


Table 3.2 In situ profiles of temperature, conductivity, pH and dissolved oxygen in No Net Loss Lake, Fort Hills Oil Sands Project, 2018 WY.

Depth (m)	Temperature (°C)					Specific Conductivity (µS/cm)					Dissolved Oxygen (mg/L)					pH				
	Mar	May	Jul	Aug	Sep	Mar	May	Jul	Aug	Sep	Mar	May	Jul	Aug	Sep	Mar	May	Jul	Aug	Sep
0.3	-	11.1	21.7	19.3	9.7	-	303	233	211	237	-	10.3	12.3	10.5	11.8	-	8.0	7.7	8.2	8.3
1.0	1.5	11.1	21.6	19.3	9.5	313	303	234	211	237	12.4	10.3	12.2	10.5	11.7	8.0	7.9	7.9	8.2	8.3
2.0	1.8	11.0	21.1	19.3	9.2	326	303	237	211	238	10.4	10.3	11.7	10.5	11.7	7.9	7.9	8.0	8.2	8.3
3.0	2.2	11.0	20.5	19.3	9.1	332	303	243	212	238	8.5	10.3	12.2	10.5	11.6	7.8	7.9	8.0	8.2	8.3
4.0	3.0	9.6	18.8	19.3	9.0	332	305	262	212	238	5.5	9.9	13.3	10.5	11.6	7.7	7.8	8.0	8.3	8.3
5.0	3.7	9.4	17.7	18.5	8.9	352	306	264	226	238	**1.4**	9.7	12.1	10.3	11.6	7.6	7.8	8.0	8.2	8.3

[1] Measurements taken in March were under the ice (ice thickness of 0.8 m).

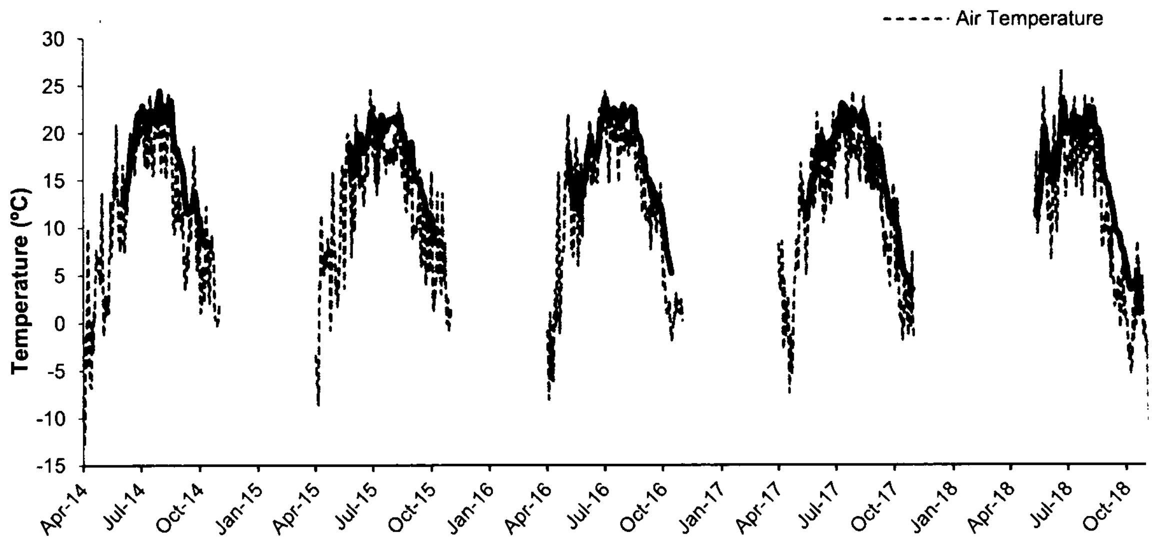
Values in bold indicate below acute GoA guideline of 5.0 mg/L (min).

Table 3.3 Late-winter (March) profiles of dissolved oxygen with depth in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

Depth (m)	Dissolved Oxygen (mg/L)			
	2015	2016	2017	2018
0.3	-	-		-
1.0	13.3	11.3	13.2	12.4
2.0	12.5	10.5	12.2	10.4
3.0	11.7	7.8	11.3	8.5
4.0	10.2	**2.9**	5.4	5.5
5.0	9.1	**2.6**	**2.1**	**1.4**
6.0	-	-	**0.6**	-

Values in bold indicate below acute GoA 2018 guideline of 5.0 mg/L (min).

Figure 3.11 Comparison of daily air temperature to daily water temperature of No Net Loss Lake from May 11 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



Note: 2015 air temperature data presented from JOSMP C1 Aurora Climate Station from May 1 to June 10, and NNLL Climate Station from June 10 to October 31.

Figure 3.12 Daily measurements of specific conductance in No Net Loss Lake from May 11 to October 15, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.

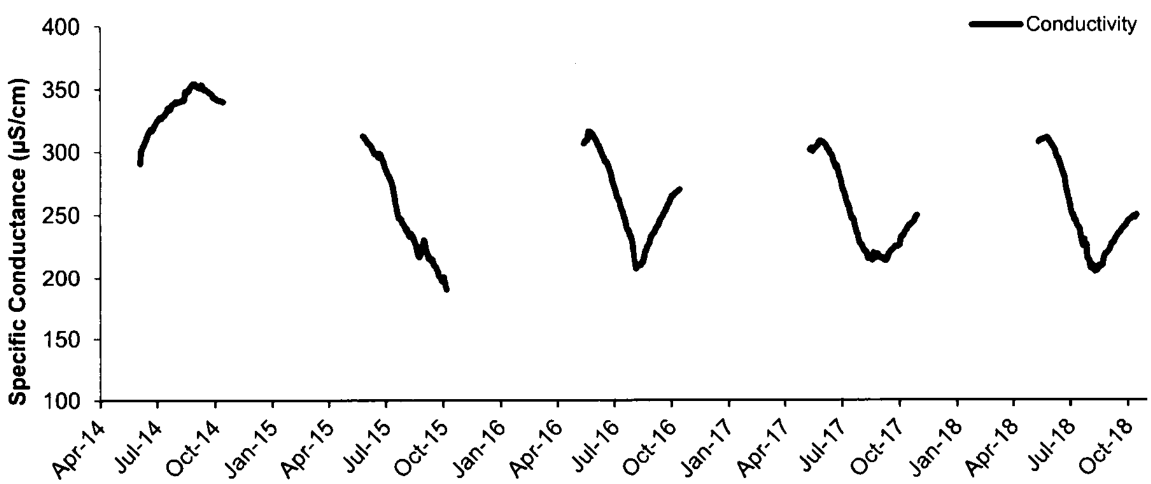


Figure 3.13 Daily measurements of pH in the No Net Loss Lake from May 11 to October 15, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.

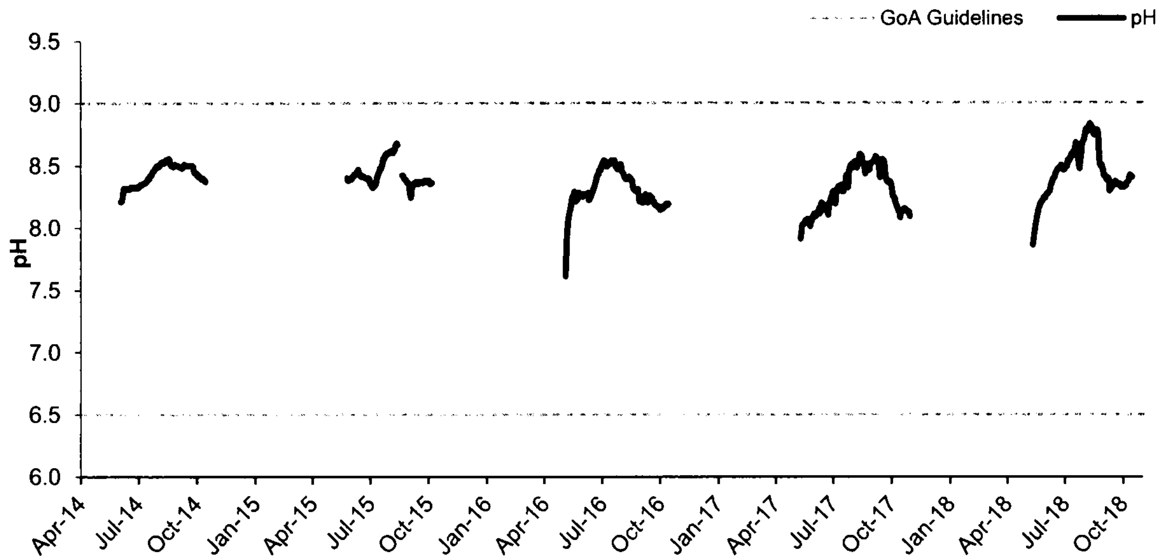
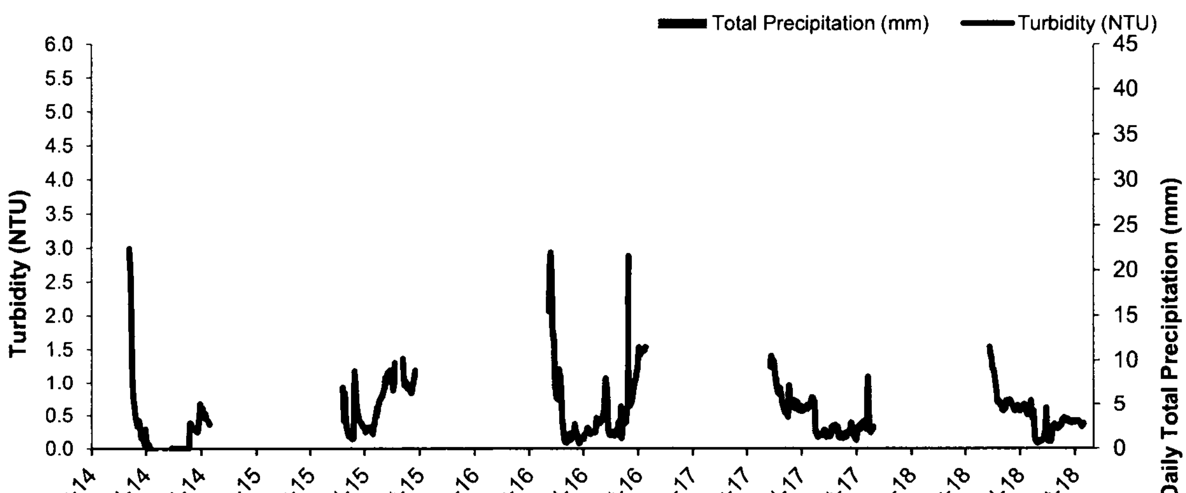


Figure 3.14 Comparison of daily precipitation to continuous measurements of turbidity in No Net Loss Lake from May 11 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



Note: Precipitation not recorded in 2014.

Figure 3.15 Daily measurements of chlorophyll *a* in the No Net Loss Lake from May 11 to October 15, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.

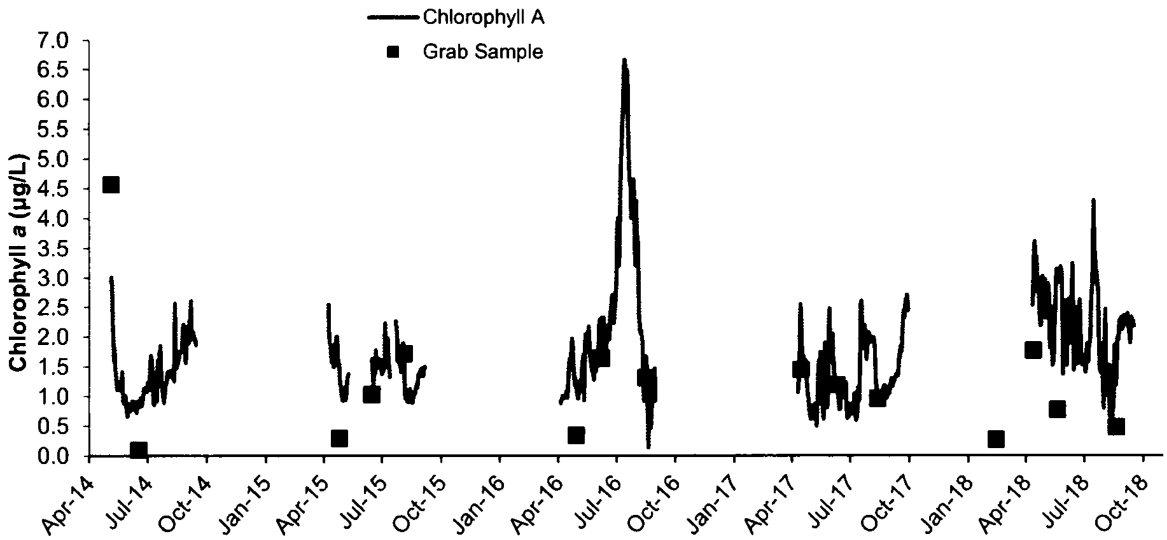
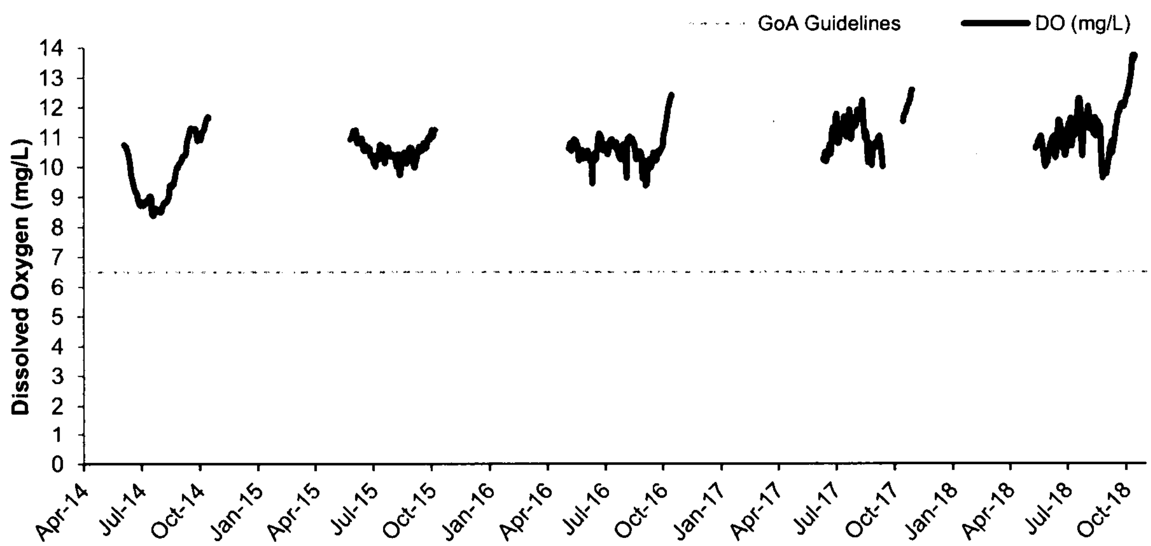


Figure 3.16 Daily measurements of dissolved oxygen in No Net Loss Lake from May 11 to October 15, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



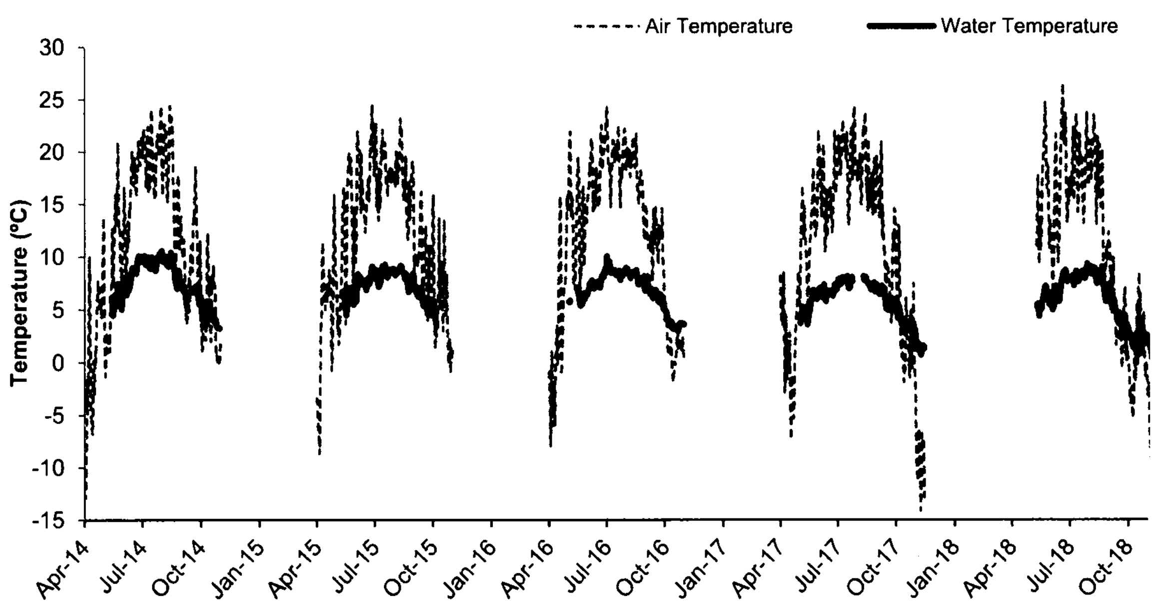
Note: Note gap in data from September 13 October 13, 2017 is the result of a malfunctioning sensor.

3.2.1.1 Creek A (Station IC1)

Continuous measurements of temperature, specific conductance, pH, and dissolved oxygen (DO) were collected in Creek A from May 10 to December 12 (Figure 3.17 to Figure 3.20). Continuous water quality data are provided in Appendix A2.

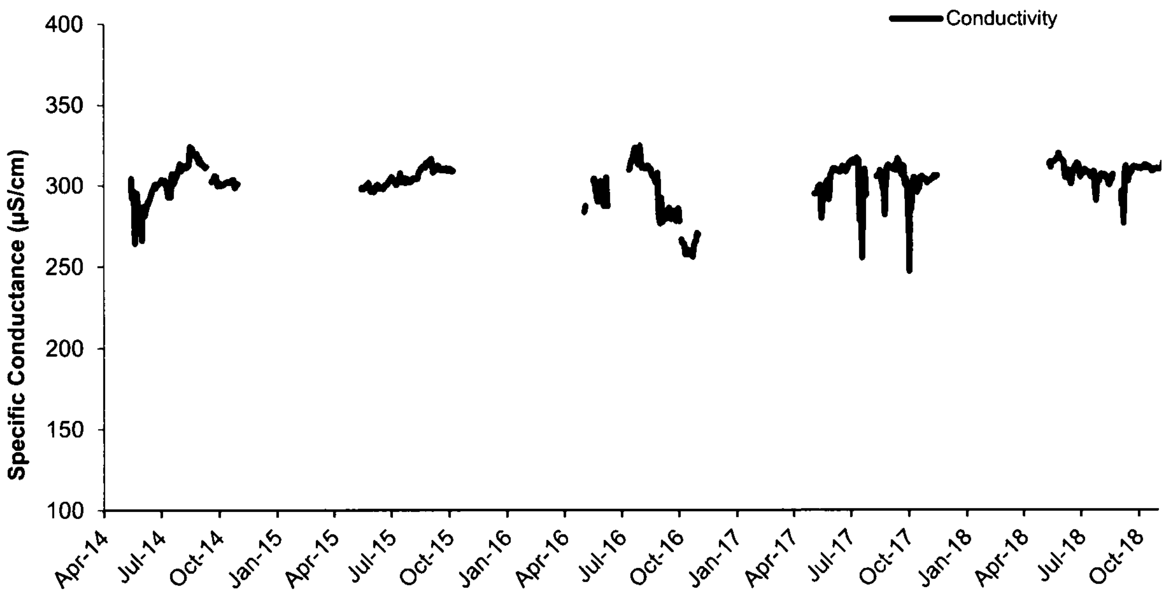
Water temperature in Creek A displayed very little fluctuation during the 2018 open-water season and was comparable to temperatures observed in previous years (Figure 3.17). Creek A is predominantly influenced by groundwater (approximately 80% by volume), which is apparent when comparing water temperature to the ambient air temperature. Specific conductance remained fairly stable in 2018 (Figure 3.12). A sudden drop in specific conductance was observed on September 6th (277 µS/cm). Causes for these sudden drops are unknown (potential debris accumulation on the sonde sensor). DO and pH also remained fairly consistent across years and seasons (Figure 3.19 and Figure 3.20) and were within guidelines for the protection of freshwater aquatic life (GoA 2018).

Figure 3.17 Comparison of daily air temperature to daily water temperature of Creek A (IC1) from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



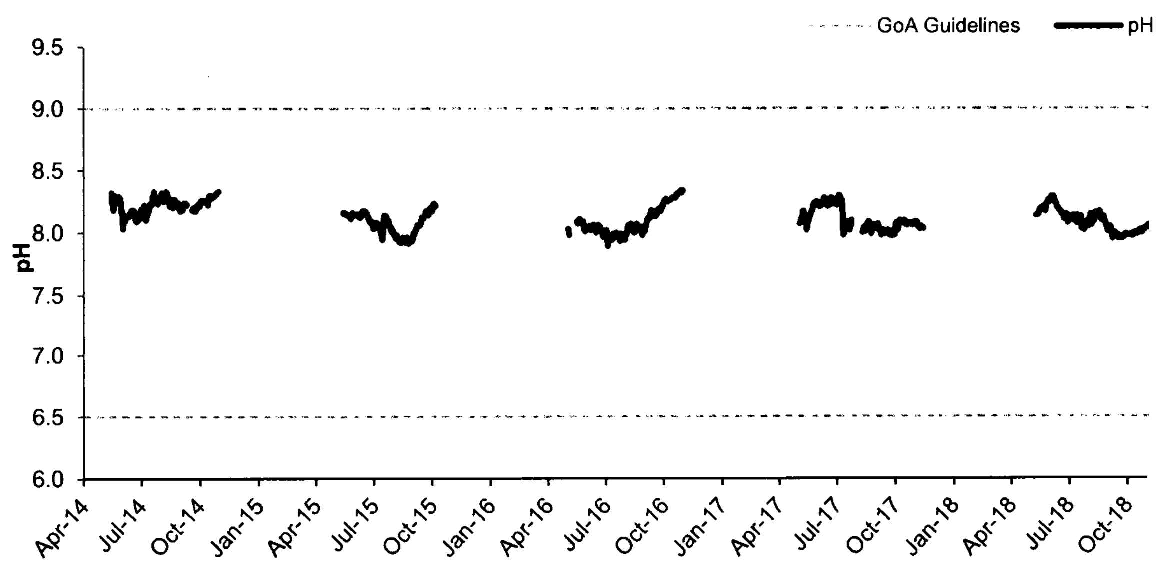
Note: 2015 air temperature data presented from JOSMP C1 Aurora Climate Station from May 1 to June 10, and NNLL Climate Station from June 10 to October 31. Gap in data from July 25 to August 9, 2017 is a result of a malfunctioning sonde.

Figure 3.18 Daily measurements of specific conductance in Creek A (IC1) May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



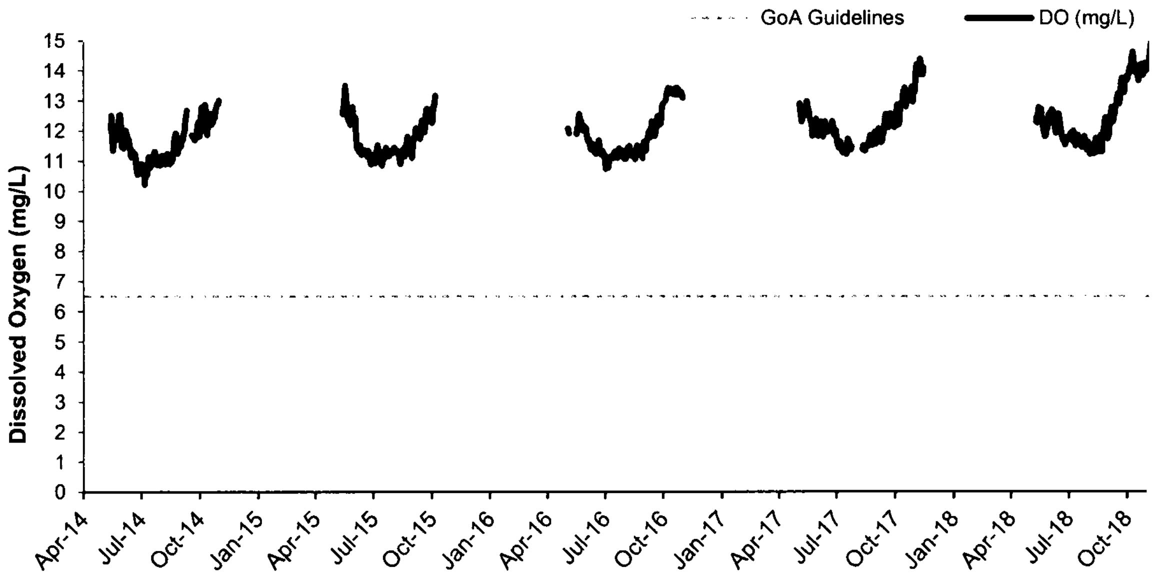
Note: Data removed from June 9 to July 11, 2016 due to anomalous results. Gap in data from July 25 to August 9, 2017 and Aug 21 to September 1, 2018 is a result of a malfunctioning sonde.

Figure 3.19 Daily measurements of pH in Creek A (IC1) from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



Note: Gap in data from July 25 to August 9, 2017 is a result of a malfunctioning sonde.

Figure 3.20 Daily measurements of dissolved oxygen in Creek A (IC1) from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



Note: Gap in data from July 25 to August 9, 2017 is a result of a malfunctioning sonde.

3.2.1.2 Outlet Channel (Stations OC1 and OC2)

Continuous measurements of temperature, specific conductance, pH, and DO were collected in the outlet channel at two locations from May 10 to November 26 (Figure 3.21 to Figure 3.28). Continuous water quality data are provided in Appendix A2.

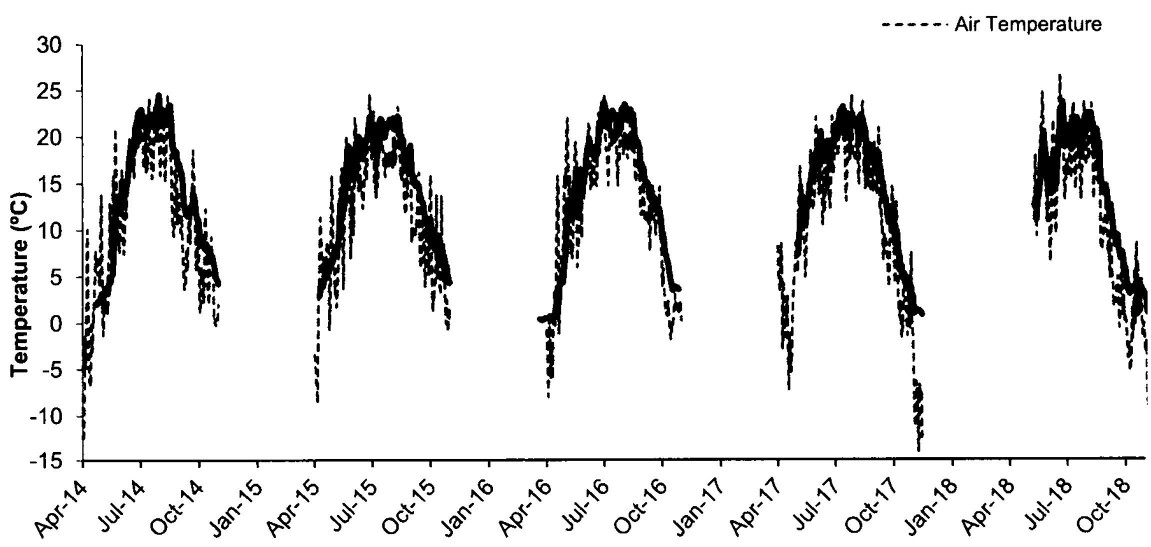
Water temperature at station OC1 generally correlated with temperature in the NNLL and the ambient air temperature. Water temperature gradually increased from 11.7°C in spring to a maximum temperature of 23.7°C in summer followed by a gradual decline to 0.6°C in late fall. This pattern of seasonal variation is similar to what was observed in previous years (Figure 3.21). Water temperature at station OC2 displayed greater seasonal variation compared to previous years with a maximum summer temperature of 14.3°C and minimum late-fall temperature of 1.7°C. Water temperature at station OC2 is influenced by groundwater from the access road cut slope ditch that discharges to the outlet channel just upstream of station OC2. Generally, this groundwater influence maintains low water temperature with little fluctuation during the open water season (Figure 3.25). In 2018, recurring beaver dam construction near the mouth of the outlet channel followed by dam removal events resulted in greater water level and temperature fluctuations at OC2.

Specific conductance fluctuated throughout the open-water season at stations OC1 and OC2; however, this variability was also observed in previous years (Figure 3.22 and Figure 3.26). Similar to 2016 and 2017 specific conductance at station OC1 displayed a larger range in values (213 µs/cm to 322 µs/cm) than was observed at station OC2 (291 µs/cm to 382 µs/cm). Historically, specific conductance at OC2 has been generally higher than OC1 due to greater groundwater contributions.

In contrast to previous years, pH at station OC1 exhibited a larger range of values (7.6 to 8.8) and greater fluctuations during the open-water season, possibly attributed to recurring beaver dam construction and removal near the mouth of the outlet channel. There was very little fluctuation in pH across the open-water season at station OC2, however pH values were generally higher in 2018 compared 2017 and 2016. All measurements of pH were within the water quality guideline for the protection of freshwater aquatic life (6.5 to 9.0, GoA 2018; Figure 3.23 and Figure 3.27).

In contrast to previous years, concentrations of DO at station OC1 in 2018 observed greater fluctuations during spring and summer before increasing in fall (Figure 3.24). Fluctuations in DO concentrations at OC1 is likely attributed to recurring beaver dam construction and removal near the mouth of the outlet channel (i.e., lower water level and higher temperature results in a decrease in DO, followed by sudden increases following dam removal). On June 19, the daily average DO concentration at station OC1 (6.3 mg/L) fell below the chronic guideline for the protection of freshwater aquatic life (6.5 mg/L, GoA 2018) and continued to fall to 5.2 mg/L (above the acute guideline of 5.0 mg/L) on June 21, until rising above guidelines following a dam removal event on June 23. At station OC2, DO was similar to previous years, ranging from 9.6 mg/L to 13.5 mg/L, with greater fluctuations during the spring and summer (Figure 3.28). DO concentrations at station OC2 remained above the acute and chronic guidelines during the entire open-water period in 2018 (Figure 3.24 and Figure 3.28).

Figure 3.21 Comparison of daily air temperature to daily water temperature at station OC1 from May 10 to October 31, 2018 relative to previous years (2014 to 2017) Fort Hills Oil Sands Project.



Note: 2015 air temperature data presented from JOSMP C1 Aurora Climate Station from May 1 to June 10, and NNLL Climate Station from June 10 to October 31.

Figure 3.22 **Daily measurements of specific conductance at station OC1 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.**

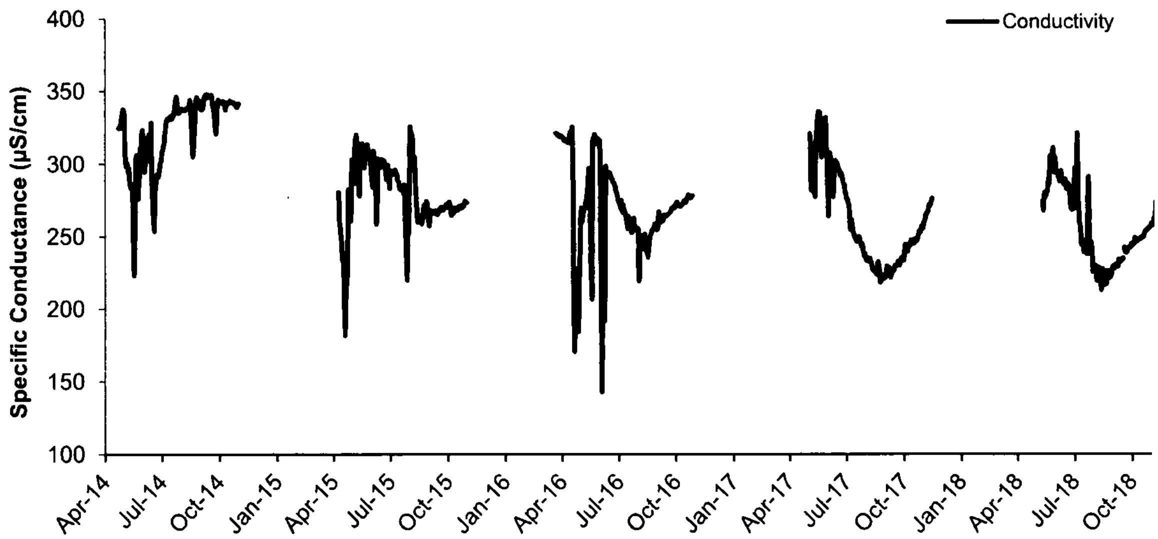
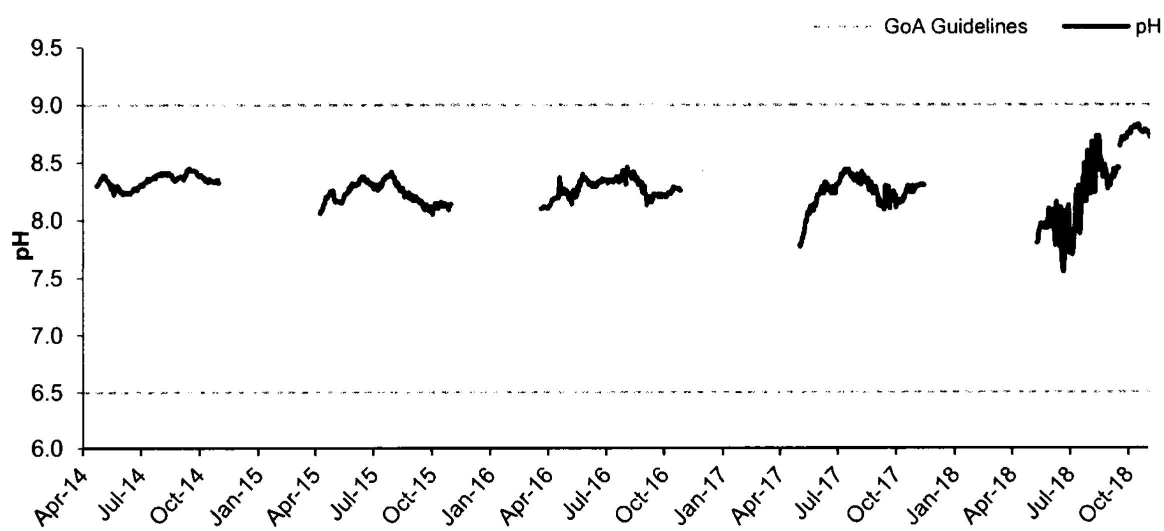


Figure 3.23 **Daily measurements of pH at station OC1 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.**



Note: Gap in data on Sep 17, 2018 is a result of a malfunctioning sonde.

Figure 3.24 Daily measurements of dissolved oxygen at station OC1 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.

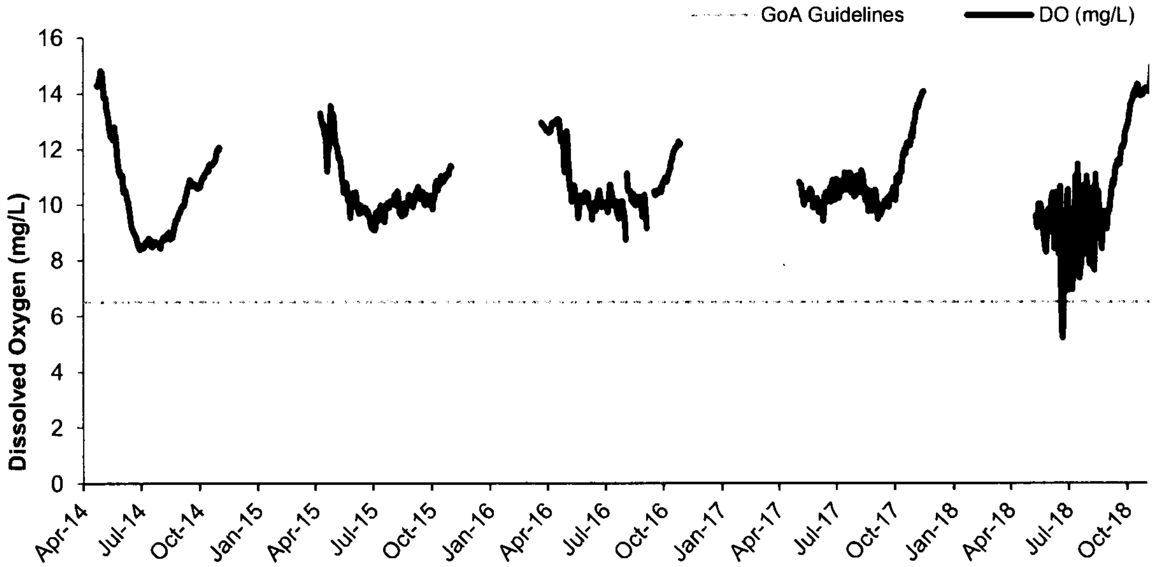
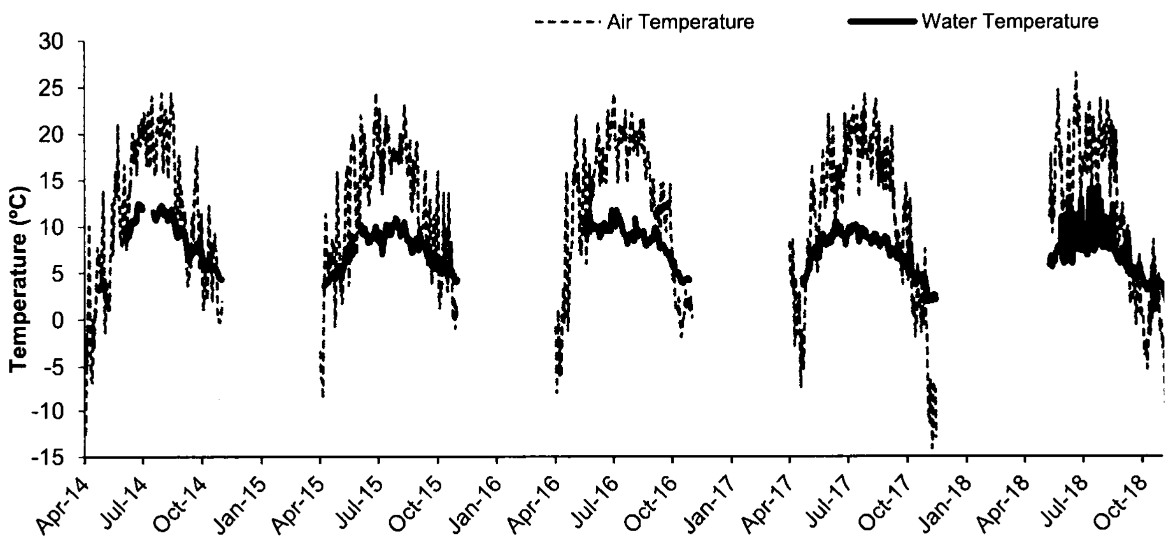


Figure 3.25 Comparison of daily air temperature to daily water temperature at station OC2 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.



Note: 2015 air temperature data presented from JOSMP C1 Aurora Climate Station from May 1 to June 10, and NNLL Climate Station from June 10 to October 31.

Figure 3.26 **Daily measurements of specific conductance at station OC2 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.**

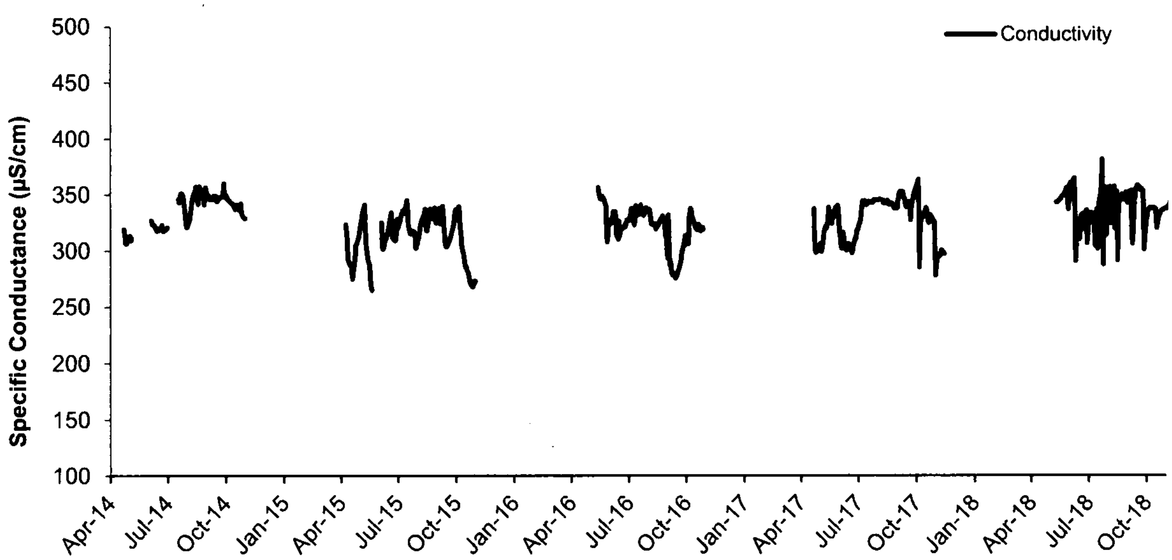


Figure 3.27 **Daily measurements of pH at station OC2 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.**

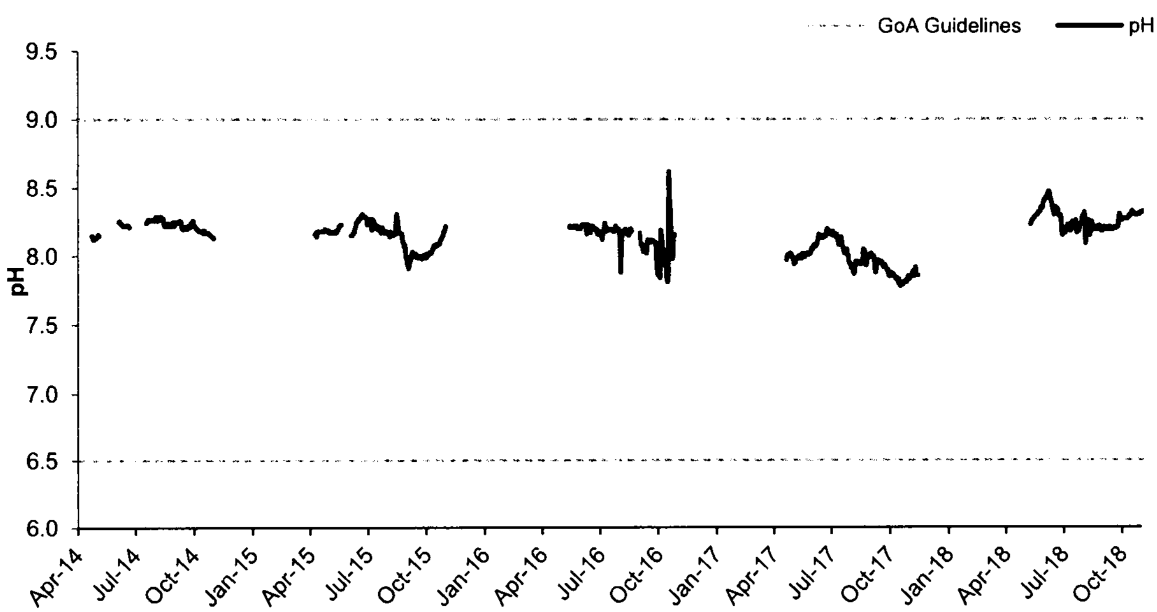
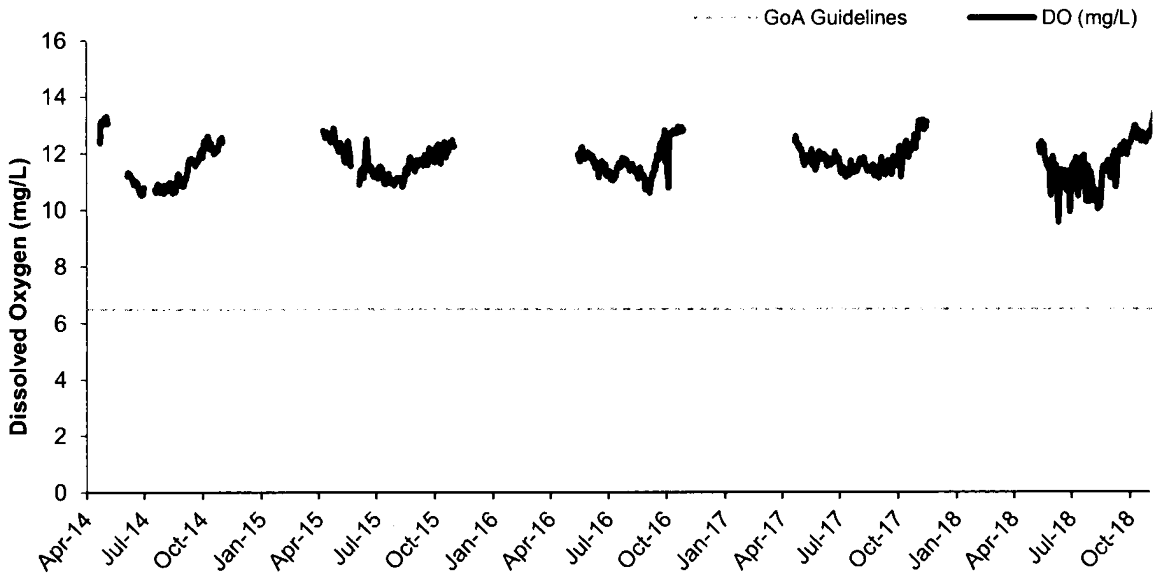


Figure 3.28 **Daily measurements of dissolved oxygen at station OC2 from May 10 to October 31, 2018 relative to previous years (2014 to 2017), Fort Hills Oil Sands Project.**



3.2.2 Analytical Water Quality

Seasonal concentrations of key water quality variables for the NNLL, Creek A (station IC1) and the outlet channel (stations OC1 and OC2) are presented in Table 3.4 to Table 3.7. Seasonal concentrations of all water quality variables (i.e., JOSMP standard analytical package) are provide in Appendix A2. Water quality of the NNLL and the outlet channel in 2018 was similar to previous years; concentrations of all variables did not exceed relevant guidelines for the protection of aquatic life (GoA 2018).

Temporal comparisons of key water quality variables for NNLL, Creek A (IC1) and the outlet channel (stations OC1 and OC2) are provided in Figure 3.29. Concentrations of total dissolved solids, total boron, dissolved selenium, and dissolved phosphorus exhibited consistent trends over time among all stations. Concentrations of total arsenic, dissolved aluminum, total selenium and total molybdenum also exhibited consistent trends over time among stations with the exception of the outlet channel at station OC2 during spring 2015 where spikes in these variables were detected as a result of the slump that occurred in the access road drainage ditch. Concentrations of total iron, total aluminum and total suspended solids were consistently higher at station OC2 when compared to other stations, but decreased from 2017 concentrations, which is likely attributed to the groundwater access road drainage ditch picking up particles from the road upstream of the station. Concentrations of naphthenic acids were elevated in the outlet channel in summer (OC2). Total Nitrogen was elevated in Creek A, the NNLL, and the outlet channel (OC1) during summer 2018.

The ionic composition of water in the NNLL and the outlet channel was consistent within a season and consisted of a calcium bicarbonate composition with temporary hardness (Figure 3.30). These results are comparable to other lakes in the region as well as to results from previous years (e.g., Shipyard Lake; JOSMP 2016 and Hatfield 2018).

Overall, water quality has remained relatively consistent across years, with very few variables exceeding guidelines for the protection of aquatic life, suggesting that the lake, inlet channel and outlet channel are providing suitable habitat for fish. This is further supported by the continued development of lower trophic levels (i.e., plankton, macrophytes and benthos) that support fish populations.

Table 3.4 Seasonal concentrations of key water quality variables measured in No Net Loss Lake, Fort Hills Oil Sands Project, 2014 to 2018 WY.

Variable	Unit	Guideline	Detection Limit	Winter 2014	Winter 2015	Winter 2016	Winter 2017	Winter 2018	Spring 2014	Spring 2015	Spring 2016	Spring 2017	Spring 2018	Summer 2014	Summer 2015	Summer 2016	Summer 2017	Summer 2018	Fall 2014	Fall 2015	Fall 2016	Fall 2017	Fall 2018
Physical variables																							
Temperature	°C	-	-	-	2.20	2.30	1.00	1.00	-	20.40	14.99	10.50	11.10	-	22.00	20.70	23.90	21.05	-	15.90	13.30	15.90	9.59
pH	pH units	6.5-9.0	0.1	-	7.92	8.07	8.10	8.19	8.10	8.17	8.40	8.17	8.24	7.94	8.34	8.33	8.37	8.11	8.42	8.27	8.21	8.40	8.24
Dissolved oxygen	mg/L	5.0 (acute) 6.5 (chronic)	-	-	14.40	11.32	11.60	13.30	-	8.50	10.05	9.60	10.20	-	10.60	10.48	10.20	12.29	-	9.80	10.18	9.95	12.71
Conductivity	µS/cm	-	2	-	321	334	356	327	325	320	319	310	296	373	286	277	247	218	357	261	286	220	261
Total suspended solids	mg/L	-	3	-	<3.0	<3.0	4.0	4.6	10.6	<3.0	<3.0	<3.0	5.9	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Nutrients																							
Dissolved organic carbon	mg/L	-	1	-	3.3	3.0	3.7	3.7	4.8	3.7	5.1	3.3	2.7	5.8	4.0	7.7	4.4	4.8	5.3	5.1	5.6	4.3	5.1
Total dissolved phosphorus	mg/L	-	0.001	-	0.0103	0.0057	0.0508	0.0074	0.0201	0.0067	0.0010	0.0074	0.0164	0.0032	0.0040	0.0022	0.0091	0.0044	<0.0010	0.0046	0.0156	0.0029	0.0168
Total nitrogen*	mg/L	-	-	-	0.239	0.223	0.253	0.222	0.474	0.222	0.222	<0.220	0.222	0.294	0.222	0.225	<0.432	0.718	0.254	0.222	0.264	<0.220	0.222
Nitrate+Nitrite	mg/L	-	0.022	-	0.039	0.023	0.053	<0.022	<0.054	<0.022	<0.022	<0.020	<0.022	<0.054	<0.022	<0.025	<0.022	<0.022	<0.054	<0.022	<0.034	<0.050	<0.022
Ammonia	mg/L	0.018 to 190[a]	0.05	-	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050
Organics																							
Total phenols	mg/L	0.004	0.001	-	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.0010
Naphthenic acids	mg/L	-	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.9	1
Ions																							
Ion balance	%	-	-	-	103	102	92	80	90	97	111	89	95	99	98	113	96	91	101	106	97.7	106	98.7
Calcium	mg/L	-	0.5	-	46.6	54.0	56.9	47.3	45.6	43.5	45.8	46.5	44.3	56.4	38.2	43.7	38	28.1	54.0	35.2	38.1	30.0[c]	33.5
Chloride	mg/L	120	0.5	-	1.1	<0.5	0.6	<0.050	1.3	0.9	0.7	0.7	1.0	1.5	0.6	0.6	<0.5	<0.50	1.1	<0.5	<0.6	<0.50	0.58
Magnesium	mg/L	-	0.1	-	9.31	9.33	9.35	9.12	8.49	9.30	9.15	8.97	8.56	10.90	9.10	9.58	9.38	8.82	9.71	8.83	9.25	9.05[c]	10.6
Sodium	mg/L	-	1	-	2.7	3.2	3.1	3.6	5.3	4.7	4.4	4.1	4.1	7.6	4.3	4.2	4.3	4.1	5.2	4.2	4.5	4.3[c]	4.5
Sulphate	mg/L	128 to 429[b]	0.3	-	12.1	12.5	13.4	9.85	32.3	20.9	14.2	11.6	10.9	39.2	19.1	15.4	12.6	11.1	28.5	16.1	13.7	11.4	10.3
Total alkalinity	mg/L		2	-	163	165	171	168	144	140	146	153	151	164	129	120	125	117	159	119	127	109	119
Total dissolved solids	mg/L		10	-	181	193	216	191	201	169	183	182	183	236	176	157	147	152	209	160	141	133	146
Selected metals																							
Total aluminum	mg/L	-	0.003	-	0.0087	0.0068	0.0136	0.0066	0.1390	0.0184	0.0228	0.0364	0.0111	0.0290	0.0102	0.024	0.0065	0.0044	0.0271	0.0083	0.0236	0.0078	0.0056
Dissolved aluminum	mg/L	0.05	0.001	-	<0.001	<0.001	0.002	<0.001	**0.062**	<0.001	0.003	0.001	<0.001	0.025	0.001	0.002	0.002	<0.0010	0.002	<0.001	<0.002	0.001	<0.0010
Total arsenic	mg/L	0.005	0.00005	-	0.000063	0.000164	0.000117	0.000175	<0.000300	0.000163	0.000186	0.000185	0.000254	0.000198	0.000204	0.000256	0.000204	0.000208	0.000174	0.000231	0.000291	<0.000300	0.0002
Total boron	mg/L	1.5	0.01	-	0.016	0.028	0.020	0.027	0.049	0.048	0.039	0.026	0.036	0.076	0.056	0.042	0.036	0.034	0.066	0.053	0.038	0.038	0.031
Total molybdenum	mg/L	0.073	0.00005	-	0.000118	0.000179	0.000152	0.000165	0.000206	0.000247	0.000212	0.000133	0.000188	0.000790	0.000248	0.000179	0.000152	0.000132	0.000166	0.000239	0.000209	0.000141	0.00014
Total strontium	mg/L	-	0.0002	-	0.0807	0.0903	0.0932	0.09	0.1090	0.1020	0.0862	0.0802	0.077	0.1410	0.1030	0.0819	0.0821	0.0753	0.1230	0.0914	0.0865	0.0748	0.0739
Total mercury	µg/L	0.013 (acute)	0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	0.0013	<0.0005	<0.0005	<0.0005	<0.0005	0.0019	<0.0005	<0.0006	<0.0007	<0.00050	0.0009	<0.0005	<0.0007	0.0005	<0.00050
Dissolved mercury	µg/L	0.005 (chronic)	0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.00050
Total vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	0.00008	<0.00005	0.00043	0.00011	0.00010	0.00009	0.00008	0.00018	0.00012	0.00013	0.000097	0.000076	0.00015	0.00013	0.00013	0.000111	0.000059
Dissolved vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	0.00027	0.00008	0.00005	<0.00005	<0.00005	0.00017	0.00010	0.000069	<0.0001	0.000057	0.00008	0.00010	0.00008	0.00009	<0.000050
Other variables																							
Biochemical oxygen demand	mg/L	-	2	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.9	<2.0	<2.0	<2.9	<2.0	<2.0	<2.0	<2.0	<2.0
Other variables that exceeded GoA (2018) guidelines in 2018.																							
None																							

Guidelines are GoA (2018); Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus Kjeldahl nitrogen (TKN); non-detectable results were assumed to be equal to the detection limit.

a: Guidelines for total ammonia are temperature and pH dependent; see GoA (2018) for additional information.

b: Hardness-dependent Guideline.

Table 3.5 Seasonal concentrations of key water quality variables measured in Creek A (station IC1), Fort Hills Oil Sands Project, 2014 to 2018 WY.

Variable	Unit	Guideline	Detection Limit	Winter					Spring					Summer					Fall				
				2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Physical variables																							
Temperature	°C	-	-	-	2.00	1.61	1.38	1.90	-	7.80	6.08	3.30	6.88	-	9.50	7.90	8.30	7.72	-	6.60	6.30	6.50	4.35
pH	pH units	6.5-9.0	0.1	-	8.00	8.19	8.16	8.22	8.09	8.31	8.08	8.26	8.34	8.15	8.27	8.33	8.23	8.19	8.41	8.26	8.30	8.51	8.03
Dissolved oxygen	mg/L	5.0 (acute) 6.5 (chronic)	-	-	13.20	13.38	13.97	13.3	-	10.20	11.62	13.03	11.7	-	10.80	11.26	11.2	11.57	-	11.60	11.82	11.67	11.63
Conductivity	µS/cm	-	2	-	306	310	313	306	279	308	305	304	293	313	305	304	294	284	314	312	327	305	312
Total suspended solids	mg/L	-	3	-	<3.0	<3.0	4.0	8.1	4.4	<3.0	<3.0	<3.0	<3.0	19.7	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Nutrients																							
Dissolved organic carbon	mg/L	-	1	-	2.9	2.1	2.6	2.2	4.5	3.3	2.9	3.5	2.5	4.6	3.5	3.4	9.9	3.7	3.5	5.7	5.4	2.7	3.9
Total dissolved phosphorus	mg/L	-	0.001	-	0.0095	0.0085	0.0106	0.0099	0.0180	0.0113	0.0102	0.0067	0.0108	0.0580	0.0127	0.0097	0.01	0.0069	0.0075	0.0116	0.0072	0.0062	0.0114
Total nitrogen*	mg/L	-	-	-	0.233	0.222	0.234	0.222	0.254	0.225	0.222	0.222	0.222	0.254	0.222	0.222	0.222	1.052	0.254	0.222	0.222	0.25	0.222
Nitrate+Nitrite	mg/L		0.022	-	0.033	<0.022	0.034	<0.022	<0.054	0.025	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.050	<0.222
Ammonia	mg/L	0.018 to 190 [a]	0.05	-	<0.05	<0.05	<0.05	<0.050	<0.050	<0.05	<0.05	<0.05	<0.050	<0.05	0.06	<0.05	<0.08	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050
Organics																							
Total phenols	mg/L	0.004	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.001
Naphthenic acids	mg/L	-	1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.4	<1.0	<1.0	1.1	<1.0	<1.0	<1.0	<1.9	1
Ions																							
Ion balance	%	-	-	-	109	98	90	81	90	102	107	85	99	98	100	114	86	90	105	100	100	104	99
Calcium	mg/L	-	0.5	-	44.8	49.3	52.0	45.1	42.4	46.9	50.6	46.7	46.6	52.8	49.2	54.5	49	44.5	52.5	49.2	52.2	56.1[c]	54.5
Chloride	mg/L	120	0.5	-	<0.5	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5	0.5	<0.5	<0.5	<0.50
Magnesium	mg/L	-	0.1	-	8.98	8.16	8.47	8.63	7.27	8.73	8.38	7.59	8.24	8.72	8.35	8.91	8.66	8.8	8.19	8.35	8.87	8.94[c]	10.4
Sodium	mg/L	-	1	-	1.9	1.8	2.0	2.0	1.7	1.9	2.0	1.8	1.8	1.9	1.8	1.7	1.9	1.8	1.8	1.9	2.0	<2.0[c]	2
Sulphate	mg/L	128 to 429 [b]	0.3	-	11.3	9.3	10.9	9.68	13.4	12.7	10.4	10.9	9.57	9.7	10.9	12.5	9.02	8.74	11.4	10.6	10.1	9.69	8.86
Total alkalinity	mg/L	-	2	-	153	155	159	158	142	144	152	158	153	166	150	139	161	161	155	158	157	159	150
Total dissolved solids	mg/L		10	-	185	198	185	176	179	173	189	176	178	202	190	186	181	193	185	190	171	183	189
Selected metals																							
Total aluminum	mg/L	-	0.003	-	0.0051	0.0062	0.0077	0.0101	0.0216	0.0090	0.0084	0.0048	0.0074	0.0723	0.0059	0.0059	0.0051	<0.0030	0.0031	0.0035	0.0035	0.0063	0.004
Dissolved aluminum	mg/L	0.05	0.001	-	<0.001	<0.001	<0.001	<0.001	0.014	<0.001	<0.001	<0.001	<0.001	-	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010
Total arsenic	mg/L	0.005	0.00005	-	0.000072	0.000064	0.000058	0.000095	<0.000200	0.000080	0.000085	0.000104	0.00008	0.000144	0.000081	0.000070	0.000071	0.000058	0.000073	0.000094	0.000063	<0.000100	0.000063
Total boron	mg/L	1.5	0.01	-	0.014	0.019	0.013	0.015	0.018	0.021	0.023	0.016	0.019	0.024	0.041	0.020	0.019	0.016	0.031	0.025	0.015	0.017	0.014
Total molybdenum	mg/L	0.073	0.00005	-	0.000116	0.000147	0.000120	0.000164	0.000159	0.000155	0.000194	0.000165	0.000158	0.000156	0.000125	0.000153	0.000137	0.000144	0.000098	0.000133	0.000154	0.000143	0.000152
Total strontium	mg/L	-	0.0002	-	0.0809	0.0689	0.0702	0.0725	0.0626	0.0808	0.0673	0.0766	0.0634	0.0705	0.0836	0.0688	0.0745	0.0703	0.0673	0.0794	0.0723	0.0750	0.0659
Total mercury	µg/L	0.013 (acute)	0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	<0.0005	0.00057	<0.0005	0.0005	<0.0005	0.0005	0.0006	<0.0005	<0.0005	0.0007	<0.0005	<0.0005	<0.00050
Dissolved mercury	µg/L	0.005 (chronic)	0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Total vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	0.000057	0.00009	<0.00005	<0.00005	<0.00005	<0.00005	0.00023	<0.00005	<0.00005	<0.00005	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050
Dissolved vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	<0.0000050	0.00009	<0.00005	<0.00005	<0.00005	<0.00005	-	<0.00005	<0.00005	<0.00005	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050
Other variables																							
Biochemical oxygen demand	mg/L	-	2	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.8	<2.0	<2.0	<2.0	<2.0	<2.0
Other variables that exceeded GoA (2018) guidelines in 2018.																							
None																							

Guidelines are GoA (2018); Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus Kjeldahl nitrogen (TKN); non-detectable results were assumed to be equal to the detection limit.

a: Guidelines for total ammonia are temperature and pH dependent; see GoA (2018) for additional information

b: Hardness-dependent Guideline

Table 3.6 Seasonal concentrations of key water quality variables measured in the outlet of No Net Loss Lake (station OC1), Fort Hills Oil Sands Project, 2014 to 2018 WY.

Variable	Unit	Guideline	Detection Limit	Winter					Spring					Summer					Fall				
				2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Physical variables																							
Temperature	°C	-	-	-	0.80	0.63	0.44	0.20	-	19.50	13.42	6.54	9.60	-	22.60	21.10	23.80	22.90	-	15.90	14.60	15.50	7.90
pH	pH	6.5-9.0	0.1	-	7.96	8.17	8.14	8.22	8.10	8.33	8.08	8.18	8.34	8.21	8.36	8.31	8.52	8.19	8.43	8.43	8.25	8.38	8.03
Dissolved oxygen	mg/L	5.0 (acute) 6.5 (chronic)	-	-	12.40	13.32	13.93	12.8	-	9.00	10.15	11.34	9.8	-	9.90	10.71	11.8	8.6	-	9.80	10.72	10.56	11.8
Conductivity	µS/cm	-	0.2	-	333	322	340	328	300	322	310	309	310	334	279	267	236	213	364	261	281	218	263
Total suspended solids	mg/L	-	3	-	<3.0	<3.0	3.0	5.7	4.2	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Nutrients																							
Dissolved organic carbon	mg/L	-	1	-	3.3	2.3	3.2	3.4	3.9	3.9	4.1	2.9	3.1	4.5	4.3	5.9	4.3	4.6	4.8	5.1	4.0	4.4	5
Total dissolved phosphorus	mg/L	-	0.001	-	0.0114	0.0058	0.0118	0.0054	0.0113	0.0053	0.0045	0.0071	0.0137	0.0045	0.0028	0.0033	0.0023	0.0032	0.0022	0.0018	0.0027	0.0022	0.0046
Total nitrogen*	mg/L	-	-	-	0.233	0.222	0.225	0.222	0.254	0.222	0.222	0.222	<0.222	0.254	0.222	0.222	<0.252	0.506	0.254	0.222	0.222	<0.250	0.222
Nitrate+Nitrite	mg/L		0.022	-	0.033	<0.022	0.025	<0.022	<0.054	<0.022	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.022	0.046	<0.054	<0.022	<0.022	<0.050	<0.022
Ammonia	mg/L	0.018 to 190[a]	0.05	-	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050
Organics																							
Total phenols	mg/L	0.004	0.001	-	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.0010
Naphthenic acids	mg/L		1	-	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<1.0	1.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ions																							
Ion balance	%		-	-	103	98	92	82	102	104	110	88	97	97	136	122	97	98	100	106	101	105	94
Calcium	mg/L	-	0.5	-	47.7	51.3	55.7	48.4	44.8	47.2	46.3	46.9	44.3	51.8	49.0	41.3	33.1	29	52.4	34.1	37.8	30.3[c]	33.4
Chloride	mg/L	120	0.5	-	0.6	1.0	0.5	<0.50	0.8	1.0	0.8	0.8	1.1	0.8	0.6	0.8	<0.5	0.6	1.1	0.5	0.6	<0.5	0.6
Magnesium	mg/L	-	0.1	-	9.89	8.77	9.63	9.45	8.48	9.52	8.99	8.36	8.56	9.55	11.40	9.42	9.2	9.26	10.00	9.08	9.34	9.24[c]	9.26
Sodium	mg/L	-	1	-	2.4	2.5	3.1	3.1	4.1	4.7	4.7	3.5	4.1	4.7	5.7	4.7	4.7	5.1	5.7	4.5	4.5	4.8[c]	5.1
Sulphate	mg/L	128 to 429[b]	0.3	-	13.6	11.1	13.1	9.83	27.2	21.8	14.9	13.3	11.4	26.0	19.6	18.2	12.7	12.8	29.8	16.7	13.6	12.2	12.8
Total alkalinity	mg/L	-	2	-	170	161	168	168	138	141	147	156	153	157	117	114	117	112	159	119	124	111	119
Total dissolved solids	mg/L	-	10	-	186	189	196	185	182	184	189	194	175	208	177	163	153	148	213	156	144	133	148
Selected metals																							
Total aluminum	mg/L	-	0.003	-	0.0092	0.0046	0.0054	0.0131	0.0635	0.0173	0.0175	0.0150	0.0196	0.0093	0.0060	0.0085	0.0054	0.0035	0.0047	0.0063	0.0098	0.0109	0.0042
Dissolved aluminum	mg/L	0.05	0.001	-	<0.001	<0.001	<0.001	<0.0010	0.035	<0.001	<0.001	<0.001	<0.0010	0.008	<0.001	0.001	0.001	<0.001	0.001	<0.001	0.002	0.001	<0.001
Total arsenic	mg/L	0.005	0.00005	-	0.000073	0.000077	0.000116	0.000115	<0.000200	0.000139	0.000176	0.000173	0.000205	0.000188	0.000203	0.000257	0.000236	0.000216	0.000147	0.000250	0.000284	<0.0003	0.000201
Total boron	mg/L	1.5	0.01	-	0.031	0.023	0.023	0.023	0.038	0.051	0.044	0.026	0.045	0.051	0.054	0.040	0.034	0.035	0.075	0.055	0.035	0.043	0.033
Total molybdenum	mg/L	0.073	0.00005	-	0.000123	0.000154	0.000157	0.000157	0.000179	0.000171	0.000185	0.000136	0.000125	0.000238	0.000166	0.000156	0.00013	0.000139	0.000175	0.000180	0.000164	0.000134	0.000131
Total strontium	mg/L	-	0.0002	-	0.0915	0.0802	0.0901	0.0852	0.0968	0.1080	0.0858	0.0868	0.0811	0.1050	0.1070	0.0806	0.0873	0.0758	0.1250	0.1000	0.0901	0.0784	0.0742
Total mercury	µg/L	0.013 (acute)	0.0005	-	<0.0005	<0.0005	<0.0005	<0.000050	0.0009	<0.0005	<0.0005	<0.0005	<0.0005	0.0006	<0.0005	0.0005	0.0016	<0.00050	0.0005	<0.0005	<0.0005	<0.0005	<0.00050
Dissolved mercury	µg/L	0.005 (chronic)	0.0005	-	<0.0005	0.0026	<0.0005	<0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005	0.0009	<0.0005	<0.0005	<0.0005	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Total vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	0.000079	0.00024	0.00011	0.00011	0.00007	0.000098	0.00012	0.00012	0.00010	0.00011	0.000088	0.00009	0.00012	0.00010	0.00011	0.000051
Dissolved vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	0.00016	0.00007	0.00006	<0.00005	<0.00005	0.00013	0.00010	0.00008	0.00008	0.000078	0.00008	0.00010	0.00008	0.00008	<0.000050
Other variables																							
Biochemical oxygen demand	mg/L	-	2	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	<2.0
Other variables that exceeded GoA (2018) guidelines in 2018.																							
None																							

Guidelines are GoA (2018); Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus Kjeldahl nitrogen (TKN); non-detectable results were assumed to be equal to the detection limit.

a: Guidelines for total ammonia are temperature and pH dependent; see GoA (2018) for additional information

b: Hardness-dependent Guideline

Table 3.7 Seasonal concentrations of key water quality variables measured in the outlet channel (station OC2), Fort Hills Oil Sands Project, 2014 to 2018 WY.

Variable	Units	Guideline	Detection Limit	Winter					Spring					Summer					Fall				
				2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Physical variables																							
Temperature	°C	-	-	-	3.00	2.28	3.21	4.80	-	10.60	9.87	6.82	8.50	-	11.50	12.50	11.60	9.90	-	10.60	9.60	7.60	6.20
pH	pH units	6.5-9.0	0.1	-	8.00	8.22	8.19	8.28	8.16	8.33	8.43	8.29	8.37	8.14	8.33	8.41	8.34	8.31	8.43	8.27	8.34	8.35	8.36
Dissolved oxygen	mg/L	5.0 (acute) 6.5 (chronic)	-	-	11.20	13.12	13.14	11.4	-	8.80	11.17	11.75	12.2	-	10.80	10.94	11.04	11.5	-	10.90	11.54	11.95	10.5
Conductivity	µS/cm	-	2	-	341	348	356	350	334	349	347	355	351	350	336	333	321	321	365	338	356	316	373
Total suspended solids	mg/L	-	3	-	7.7	8.0	27.0	10.3	11.7	1120.0	13.3	5.7	8.9	<3.0	16.6	10.2	<3.0	<3.0	13.0	11.2	3	<3.0	<3.0
Nutrients																							
Dissolved organic carbon	mg/L	-	1	-	1.8	1.9	2.3	2.6	5.4	2.7	2.5	3.1	2	3.0	2.6	2.7	2.8	3.1	2.8	4.1	3.3	2	3.1
Total dissolved phosphorus	mg/L	-	0.001	-	0.0045	0.0026	0.0088	0.0026	0.1970	0.0018	0.0039	0.0018	0.0023	0.0051	0.0026	0.0025	0.0024	0.0031	0.0066	0.0032	0.001	0.0027	0.0018
Total nitrogen*	mg/L	-	-	-	0.222	0.222	<0.222	0.222	0.254	0.512	0.222	<0.222	0.222	0.254	0.222	0.222	<0.222	0.222	0.254	0.222	0.222	<0.250	0.262
Nitrate+Nitrite	mg/L	-	0.022	-	<0.022	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.022	<0.022	<0.054	<0.022	<0.022	<0.050	<0.022
Ammonia	mg/L	0.018 to 190[a]	0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.417	<0.050	<0.05	<0.05	<0.05	<0.05	<0.050
Organics																							
Total phenols	mg/L	0.004	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.001	<0.001	<0.0010
Naphthenic acids	mg/L		1	-	<1.0	<1.5	<1.0	<1.0	<1.0	<1.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0	1.1	<1.0	<1.0	<1.0
Ions																							
Ion balance	%	-	-	-	101	97	89	86	102	101	111	92	97	98	104	111	95	98	101	104	97	112	94
Calcium	mg/L	-	0.5	-	49.7	54.6	58.3	55.9	49.9	52.7	53.1	52.5	55.5	57.5	52.9	56.2	57.3	54.7	57.4	52.3	55.5	60.0[c]	59.0
Chloride	mg/L	120	0.5	-	<0.5	<0.5	0.6	<5.0	0.7	0.5	0.5	0.8	1.2	<0.5	<0.5	0.7	0.7	1.2	0.6	1.1	1.0	0.7	1
Magnesium	mg/L	-	0.1	-	9.51	8.88	9.10	9.31	9.35	9.63	9.54	8.57	9.27	9.88	9.42	10.00	9.53	9.43	9.45	9.23	9.52	9.51[c]	11.1
Sodium	mg/L	-	1	-	2.5	2.5	2.6	2.8	3.6	3.0	3.6	3.1	2.7	3.3	2.9	3.6	3	2.5	3.4	3.3	3.1	2.8[c]	2.8
Sulphate	mg/L	128 to 429[b]	0.3	-	14.2	14.1	15.7	13.2	28.5	19.7	17.4	16.6	17.1	23.6	18.9	22.8	15.8	18.5	21.6	21.3	18.6	15.5	17.7
Total alkalinity	mg/L	-	2	-	174	170	176	177	158	160	164	169	174	173	155	146	168	168	172	158	166	163	172
Total dissolved solids	mg/L	-	10	-	181	205	200	210	203	232	206	201	205	220	211	213	195	236	216	204	179	197	212
Selected metals																							
Total aluminum	mg/L	-	0.003	-	0.0986	0.1040	0.2930	0.0579	0.1510	18.1000	0.1440	0.5080	0.0758	0.0112	0.1810	0.1980	0.0254	0.0073	0.0207	0.1310	0.0174	0.0342	0.0097
Dissolved aluminum	mg/L	0.05	0.001	-	0.005	<0.001	0.001	<0.001	**0.060**	0.037	0.004	0.002	0.010	<0.001	<0.001	0.002	<0.001	<0.0010	0.002	<0.001	0.001	0.001	<0.0010
Total arsenic	mg/L	0.005	0.00005	-	0.000171	0.000174	0.000238	0.000172	<0.000300	**0.011700**	0.000227	0.000458	0.000167	0.000171	0.000231	0.000288	0.000169	0.000112	0.000154	0.000263	0.000171	<0.000200	0.000127
Total boron	mg/L	1.5	0.01	-	0.023	0.022	0.020	0.019	0.034	0.073	0.033	0.027	0.025	0.039	0.051	0.031	0.023	0.019	0.070	0.041	0.026	0.025	0.021
Total molybdenum	mg/L	0.073	0.00005	-	0.000150	0.000156	0.000156	0.000138	0.000180	0.000862	0.000202	0.000160	0.000158	0.000185	0.000141	0.000160	0.000145	0.000133	0.000131	0.000158	0.000147	0.000135	0.000148
Total strontium	mg/L	-	0.0002	-	0.0975	0.0909	0.0870	0.0838	0.0998	0.2560	0.0860	0.0907	0.0801	0.0998	0.0974	0.0841	0.0873	0.0795	0.0950	0.0874	0.0894	0.0795	0.0822
Total mercury	µg/L	0.013 (acute)	0.0005	-	<0.0005	<0.0005	0.0008	<0.0005	0.0009	**0.0860**	<0.0005	0.0023	0.0005	<0.0005	0.0009	0.0009	0.0009	<0.00050	0.0006	0.0007	<0.0005	<0.0005	<0.00050
Dissolved mercury	µg/L	0.005 (chronic)	0.0005	-	<0.0005	0.0017	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.00050	<0.0005	<0.0005	<0.0005	<0.0005	<0.00050
Total vanadium	mg/L	-	0.00005	-	0.00023	0.00025	0.00081	0.000169	0.00046	0.06010	0.00041	0.00158	0.000226	0.00007	0.00048	0.00056	0.00010	<0.000050	0.00009	0.00049	0.00009	0.00012	<0.000050
Dissolved vanadium	mg/L	-	0.00005	-	<0.00005	<0.00005	<0.00005	<0.00005	0.00026	0.00046	0.00005	0.000061	0.000076	<0.00005	<0.00005	0.00005	0.000050	<0.000050	<0.00005	<0.00005	<0.00005	<0.00005	<0.000050
Other variables																							
Biochemical oxygen demand	mg/L	-	2	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Other variables that exceeded GoA (2018) guidelines in 2018.																							
None																							

Guidelines are GoA (2018); Values in bold indicate concentrations exceeding guidelines for the protection of aquatic life.

* Total nitrogen = Nitrate+nitrite plus Kjeldahl nitrogen (TKN); non-detectable results were assumed to be equal to the detection limit.

a: Guidelines for total ammonia are temperature and pH dependent; see GoA (2018) for additional information

b: Hardness-dependent Guideline

Figure 3.29 Key water quality variables for No Net Loss Lake (PZ1), Creek A (IC1) and the outlet channel (OC1 and OC2), Fort Hills Oil Sands Project, 2014-2018.

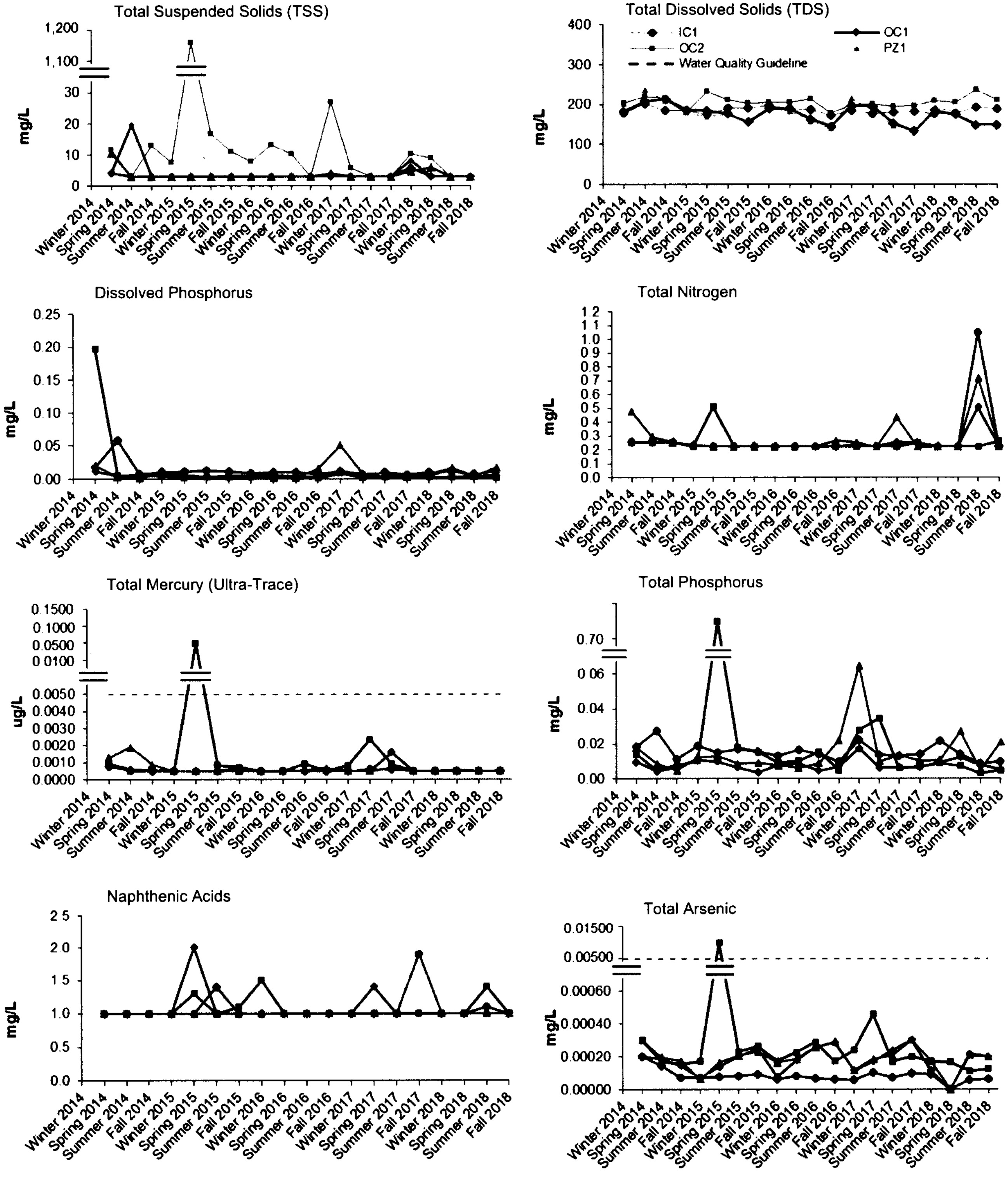


Figure 3.29 (Cont'd.)

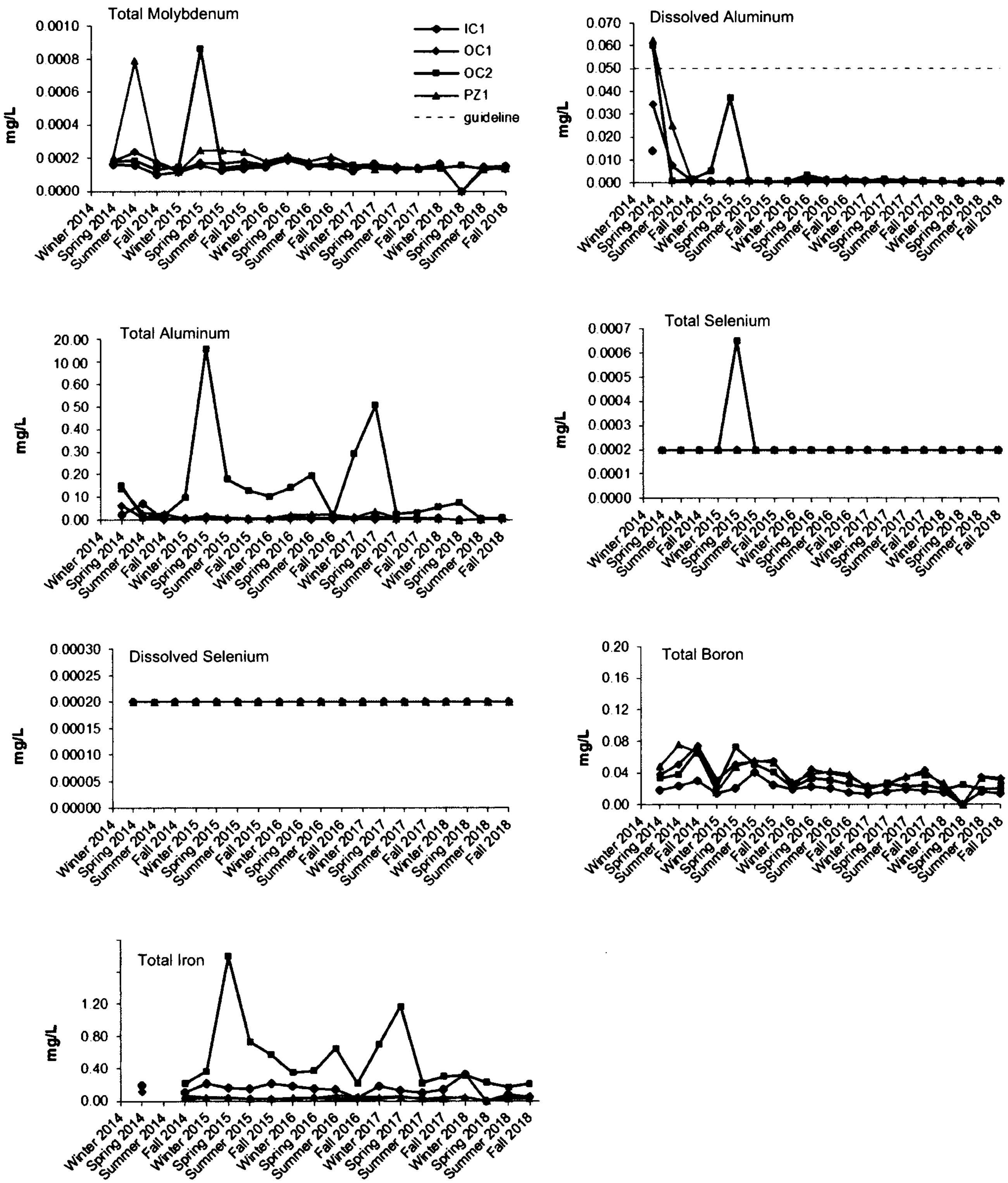
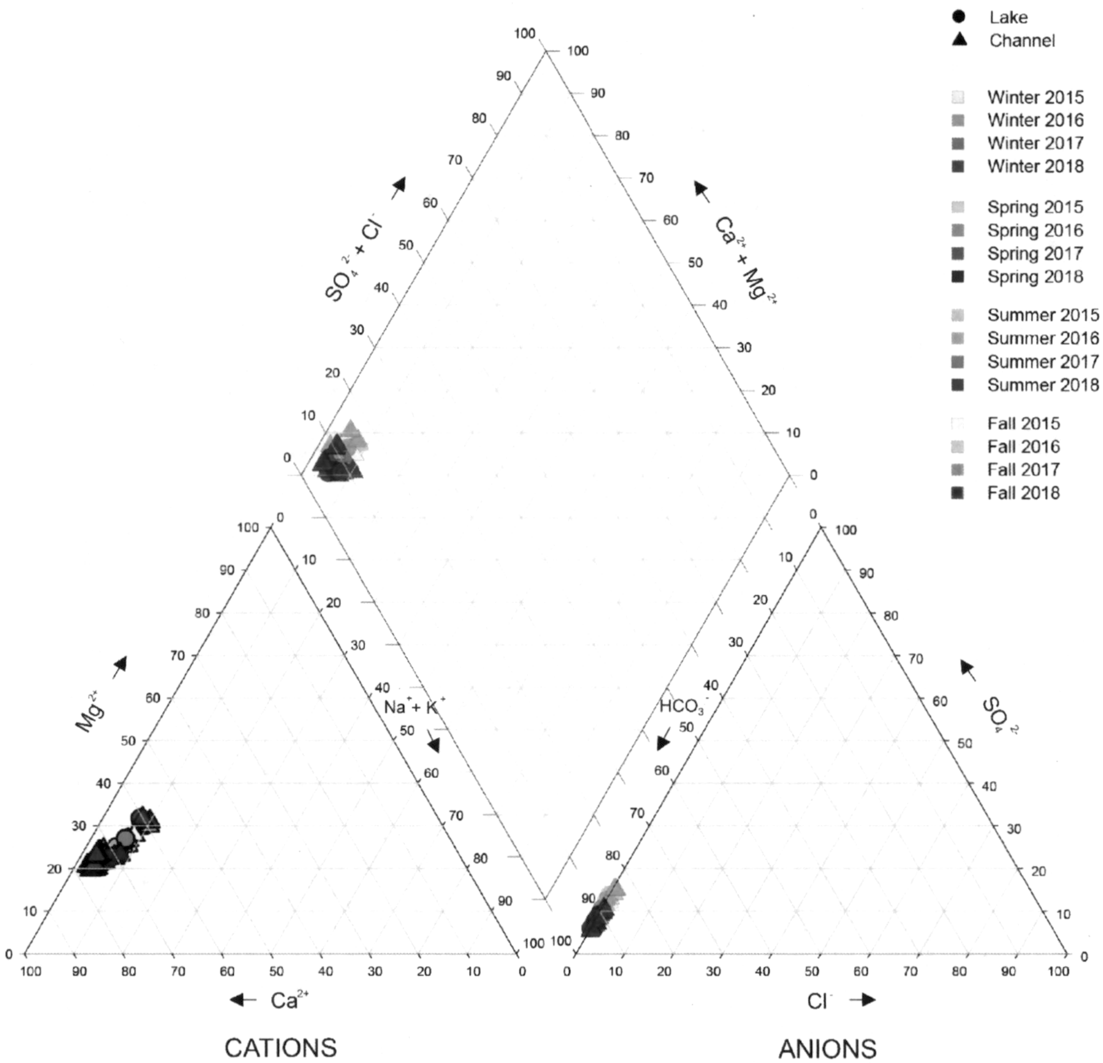


Figure 3.30 Piper diagram of ion concentrations of water in the No Net Loss Lake and the outlet channel, Fort Hills Oil Sands Project, 2015-2018 WY.



3.3 PLANKTON COMMUNITIES

Seasonal succession of phytoplankton is often characterized by low biomass in winter due to low temperatures and limited light penetration under ice, followed by a peak in spring as temperature, light, and nutrient availability increases (Wetzel 1983). Occasionally, there is a second peak in fall as lake mixing occurs (Wetzel 1983). Biomass then typically decreases in late spring and summer as lakes experience thermal stratification and zooplankton predation increases (Wetzel 1983). Although the NNLL experiences very little thermal stratification, these seasonal patterns in phytoplankton abundance and biomass were observed in the NNLL during the 2018 monitoring year (Table 3.8 and Figure 3.31). A zooplankton community typically shows variation across seasons in response to changing light conditions, water temperature, DO, food supply, and predation (Wetzel 1983). Typically, zooplankton biomass peaks in the summer following a large increase in food availability (i.e., spring phytoplankton growth). In 2018 there was less seasonal variation in zooplankton abundance and biomass compared to previous years (Figure 3.31), with an increase in biomass observed in fall, likely in response to a peak in phytoplankton in August. Currently plankton sampling occurs in March, May, July and September; however, a peak in chlorophyll *a* measured at station PZ1 suggests an increase in phytoplankton biomass during this time (Figure 3.15). Seasonal patterns of plankton community abundance and biomass across years are presented in Table 3.8 and Figure 3.31 to Figure 3.35.

Similar to previous years, Chrysophyceae (golden-brown algae) were the most abundant phytoplankton taxa in the NNLL, with the exception of winter where Chlorophyceae (green algae) were the most abundant taxa (Figure 3.32). With the exception of the spring phytoplankton, biomass was slightly lower in 2018 compared to previous years (Figure 3.31). Taxa richness and diversity were generally similar to 2017 with the exception of summer (higher richness and diversity in 2018) and winter (higher diversity in 2017) (Figure 3.36). Evenness in 2018 was slightly lower in all seasons except summer (Table 3.8 and Figure 3.36). Consistent with previous years evenness is considered relatively low, which suggests the plankton community was dominated by only a few select taxa (Table 3.8 and Figure 3.36).

Similar to previous years, freshwater rotifers (Monogononta) were the most abundant zooplankton across seasons (Figure 3.34). Although not the most abundant, crustaceans (Branchiopoda and Copepoda) had the highest biomass across all seasons (Figure 3.35). Zooplankton richness in 2018 was similar to previous years, with a slight decrease from 2017 in the fall (Figure 3.36). Simpson's diversity ratings and evenness for the zooplankton community were within the range of previous years, with the exception of spring, where both metrics were lower than all previous years, suggesting a moderately less diverse zooplankton community. Evenness of the zooplankton community in NNLL is generally low (i.e., <0.2) as a result of the disproportionate number of freshwater rotifers present during each season (Table 3.8 and Figure 3.36).

The seasonal pattern of succession demonstrated in the lake in 2018 was consistent with natural lake environments in northern Alberta (University of Alberta 1990), indicating that the productivity of the NNLL has a lower trophic structure that can support benthic invertebrate communities and fish populations. As predicted in Golder 2006, phytoplankton and zooplankton have naturally colonized NNLL within the first few years following construction. The level of abundance and biomass suggests NNLL is progressing towards a productive lake ecosystem.

Table 3.8 Seasonal summary of plankton indices for No Net Loss Lake, Fort Hills Oil Sands Project, 2018 WY.

Index	Winter	Spring	Summer	Fall
Phytoplankton				
Total Abundance (units/m^3)	546,200,000	1,298,000,000	733,800,000	102,000,000
Total Biomass (mg/m^3)	188	880	300	53
Total Richness (No. of Taxa)	15	16	23	5
Simpson's Index of Diversity	0.26	0.67	0.55	0.54
Evenness	0.27	0.19	0.10	0.15
Zooplankton				
Total Abundance (units/m^3)	74,134	106,530	134,406	90,777
Total Biomass (mg/m^3)	144	120	200	391
Total Richness	11	16	11	11
Simpson's Index of Diversity	0.23	0.26	0.35	0.48
Evenness	0.12	0.08	0.14	0.17

Figure 3.31 Seasonal abundance and biomass of phytoplankton and zooplankton in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

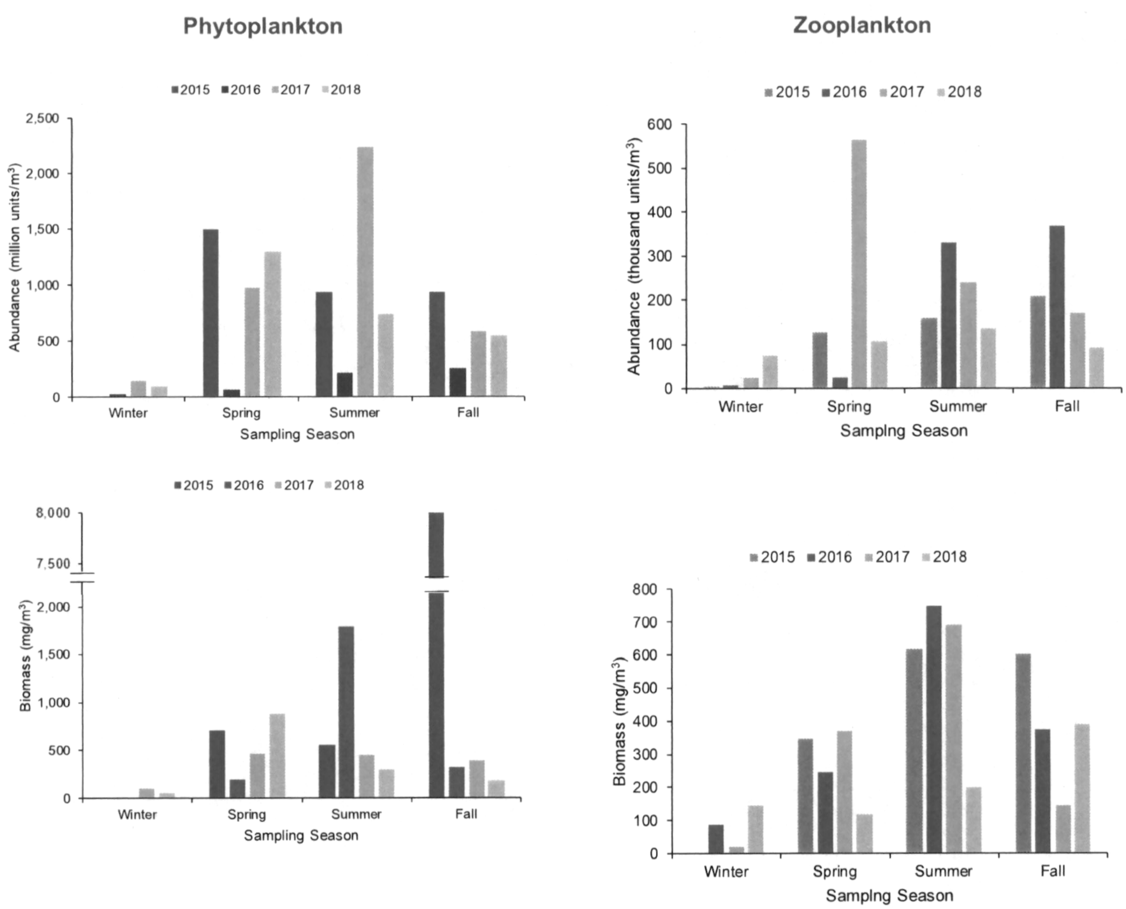


Figure 3.32 Seasonal abundance of phytoplankton taxa in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

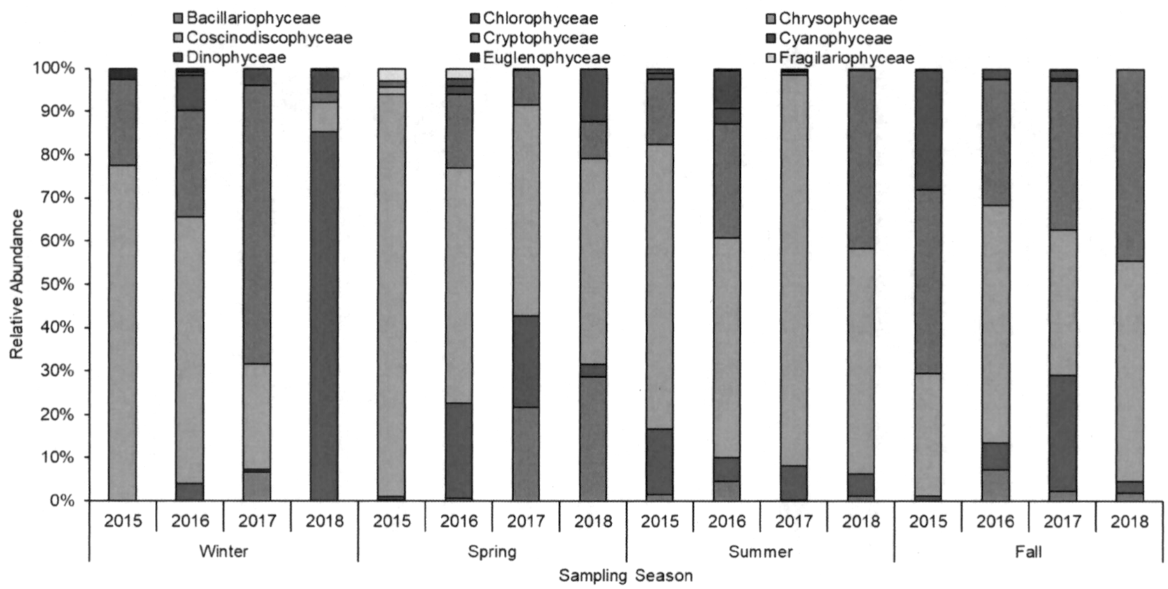


Figure 3.33 Seasonal biomass of phytoplankton taxa in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

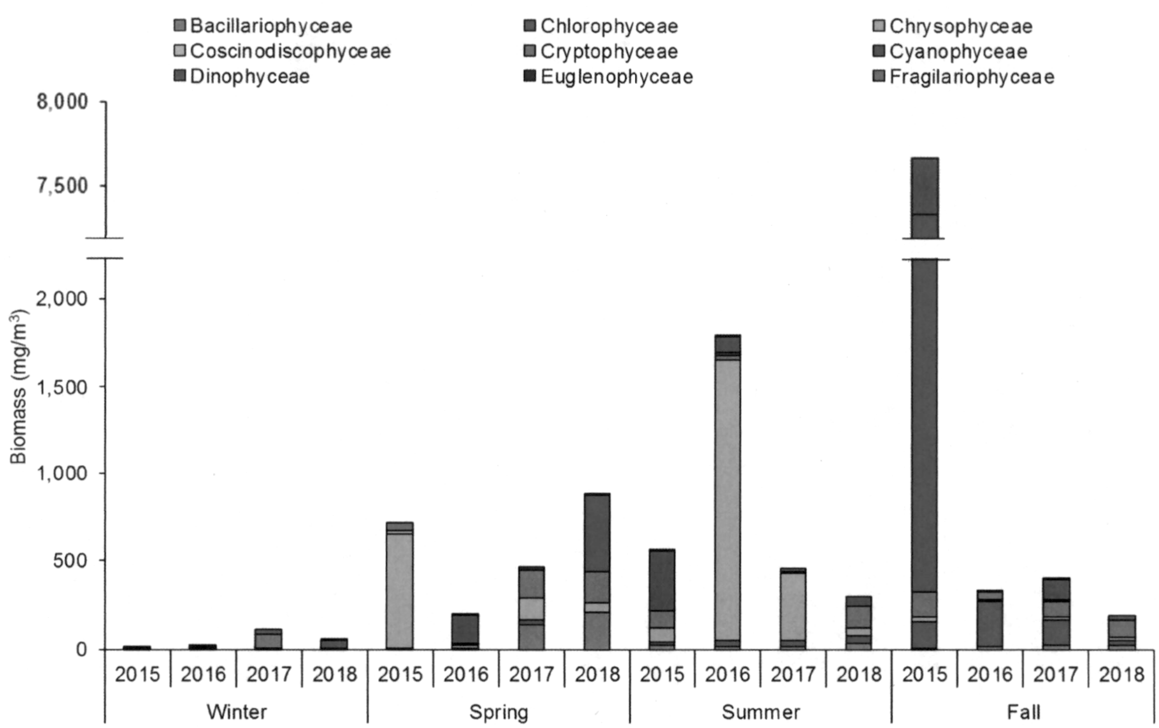


Figure 3.34 Seasonal abundance of zooplankton taxa in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

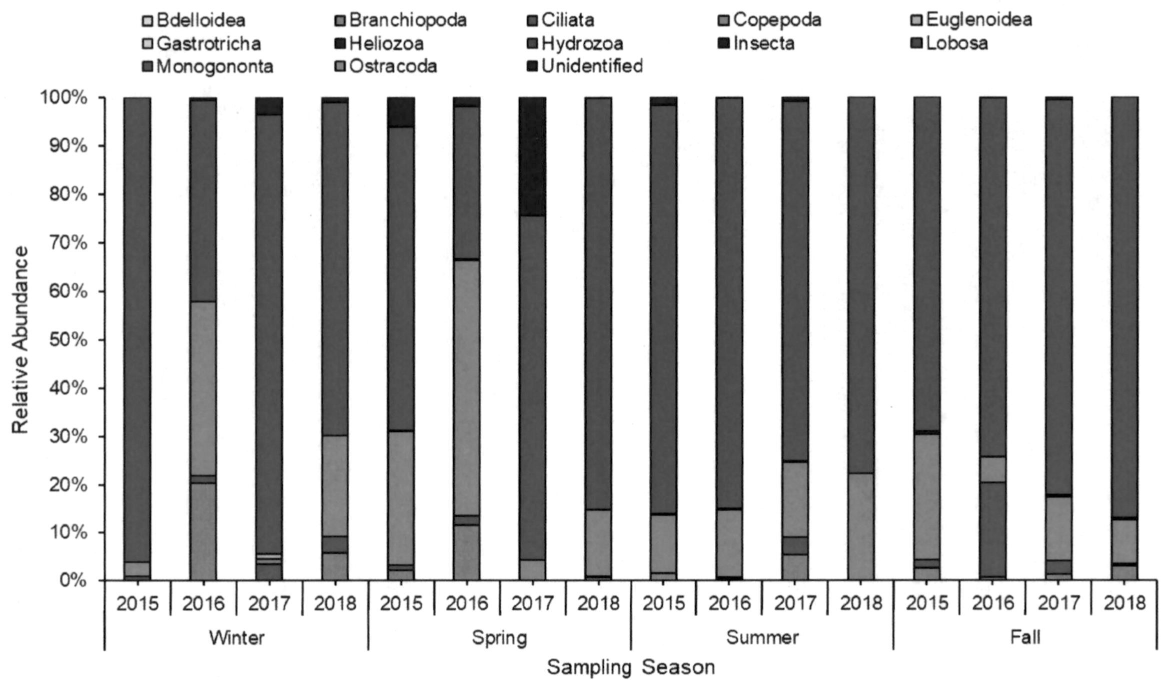


Figure 3.35 Seasonal biomass of zooplankton taxa in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

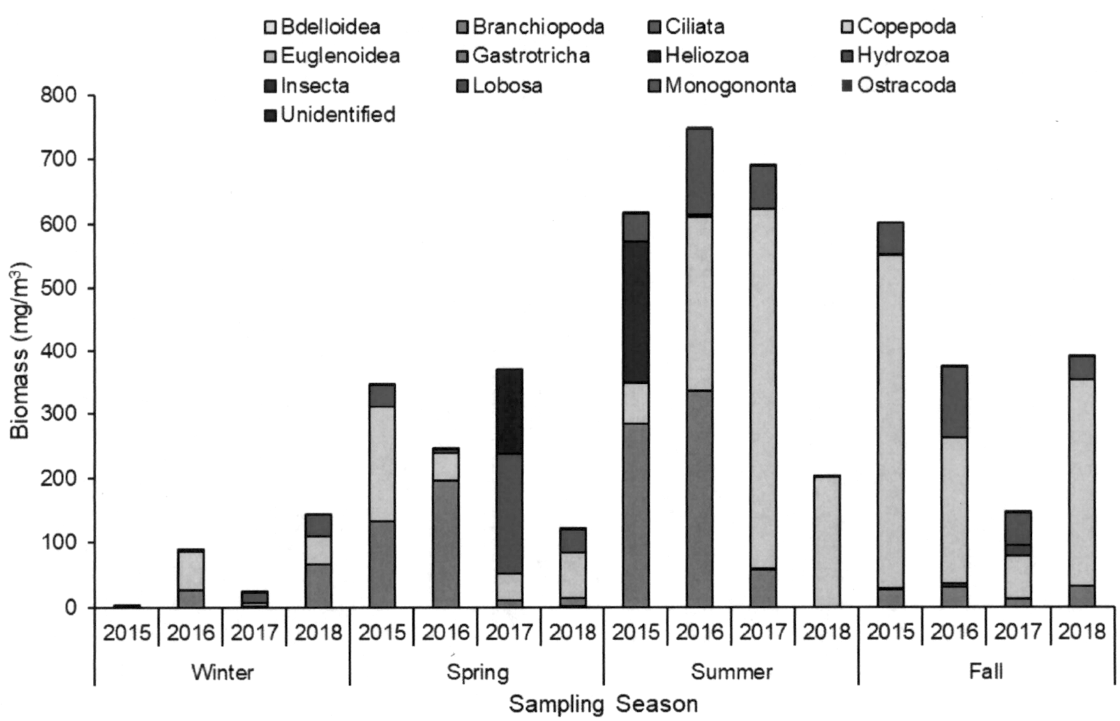
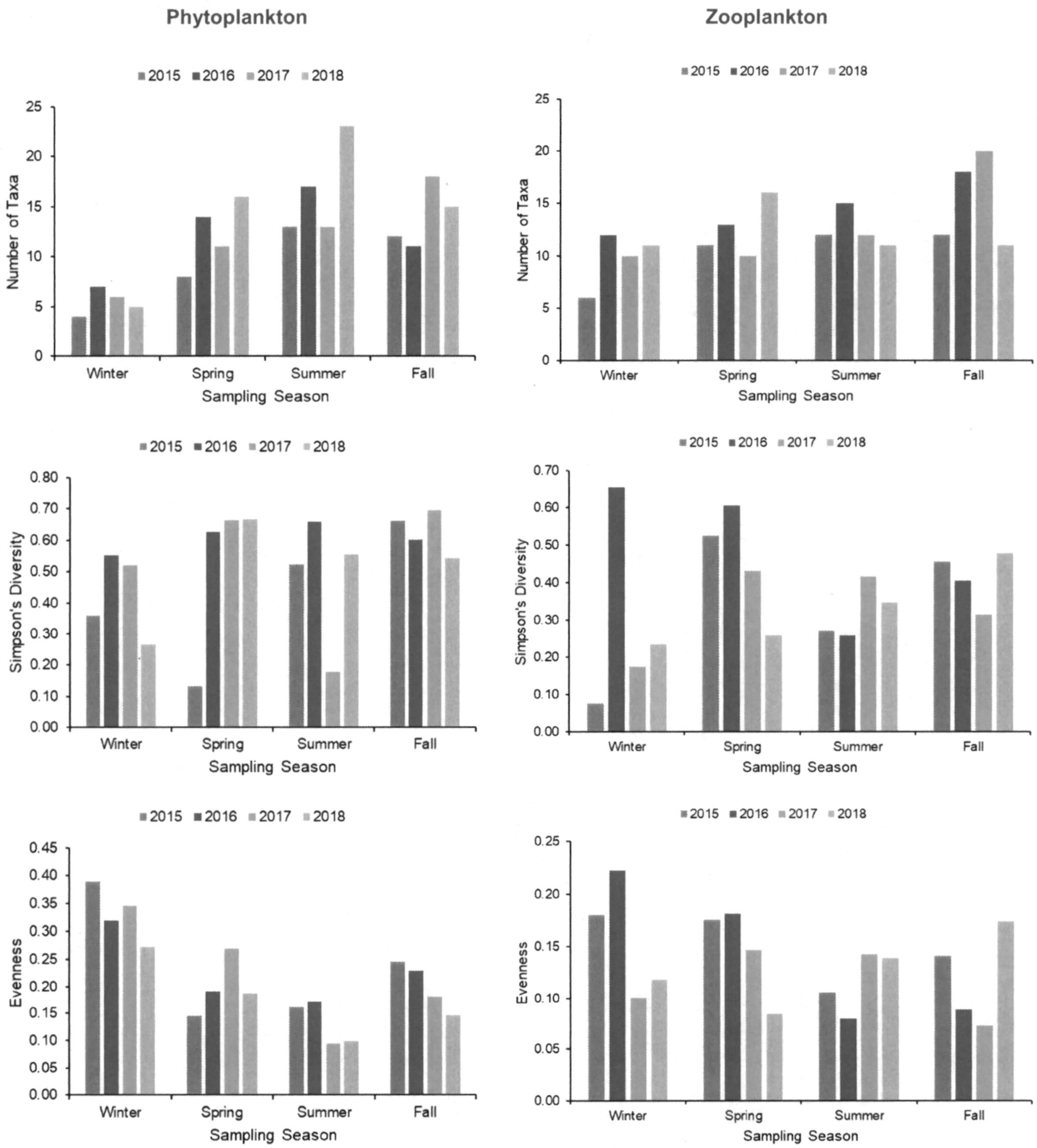


Figure 3.36 Seasonal richness, diversity, and evenness of phytoplankton and zooplankton in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



3.4 BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY

3.4.1 Benthic Invertebrate Communities

A summary of the Fort Hills NNLL benthic invertebrate community metrics is presented in Table 3.9. In 2018, benthic invertebrate density at littoral sampling stations increased from 2017 levels across all littoral sampling stations. Density means at each station ranged from 39,267 to 120,474 invertebrates/m^2 with the highest density found at LZ-2 (Figure 3.37). At the pelagic sampling station (PZ-1), density was higher than previous years with a mean of 22,385 invertebrates/m^2 (Table 3.9; Figure 3.37).

The number of taxa within the littoral zone varied across stations and was higher than in 2017 ranging from 18 to 31 taxa (Table 3.9; Figure 3.38). Taxonomic richness was higher at the pelagic station in 2018 compared to previous years with a mean of 15 taxa (Table 3.9). Three new taxa were identified across sampling stations and included Aeshnidae (dragonfly), Dytiscidae (beetle), and Elmidae (beetle) (Table 3.10). Community diversity (Simpson's Diversity Index; Figure 3.39) was the same or slightly higher in 2018 and ranged from a mean of 0.76 to 0.90 across the littoral stations (Table 3.9). Average evenness at littoral stations was slightly lower in 2018 (0.29 in 2018, 0.31 in 2017), ranging from 0.21 to 0.38 (Table 3.9; Figure 3.40). Evenness at PZ-1 was lower than previous years (0.28) due to this site being dominated by a small number of taxa.

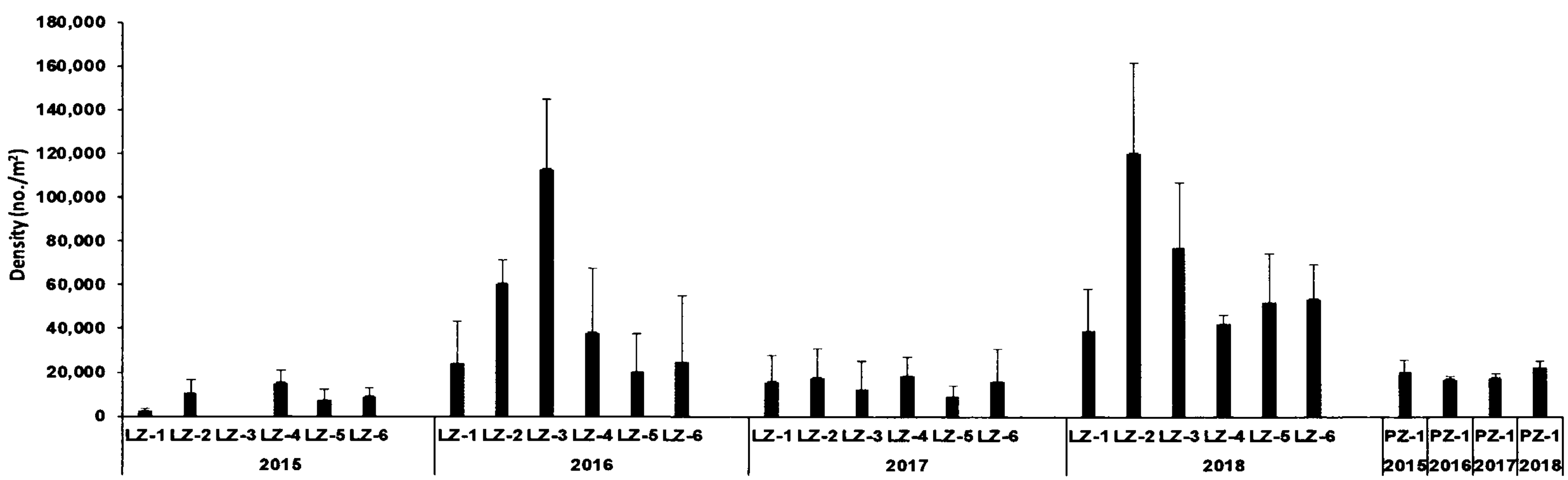
As illustrated in Figure 3.41, the benthic community demonstrated a change in the relative abundance of taxa from 2017. In 2018, the proportion of Oligochaeta (worms) decreased from 2017 levels (45%) to a littoral mean of 14%. Chironimidae (midges) increased from 2017 levels (37%) to a littoral mean of 64%, making them the most abundant taxa. The relative abundance of other taxa remained relatively stable between 2017 and 2018 (Figure 3.41). Ephemeroptera (mayflies) were present at all littoral stations comprising an overall mean of 7% of the littoral community, which is an increase from 3% in 2017. At the pelagic station (PZ-1), the benthic invertebrate community was similar to previous years with chironomids remaining as the dominant taxa (mean of 46% of the community; Figure 3.41). Ostracods and oligochaetes also contributed moderate proportions of the density at PZ-1 with a relative abundance of 27% and 24%, respectively. Unlike the littoral stations, ostracods showed an increase in abundance at the pelagic station in 2018. The more sensitive ETO taxa were again present at all littoral stations and increased from 4% in 2017 to 10% in 2018 (Figure 3.42). However, ETO taxa remained below levels observed in 2015 and 2016. Members of all three of the ETO taxa were observed at station PZ-1 in 2018. ETO taxa increased from 0.1% in 2017 to 0.7% in 2018. Greater depths and particle size of sediment, such as the greater proportion of silt (Table 3.11), may explain the lack of ETO taxa in the pelagic zone.

Table 3.9 Mean benthic invertebrate community metrics in No Net Loss Lake, Fort Hills Oil Sands Project, (2015 to 2018).

Metric	Sampling Area and Year															
	Littoral								Pelagic							
	2015	SE[1]	2016	SE[1]	2017	SE[1]	2018	SE[1]	2015	SE[1]	2016	SE[1]	2017	SE[1]	2018	SE[1]
Density (no./m^2)	8,966	1,528	46,968	9,254	15,031	2,408	64,214	8,487	20,374	3,068	17,170	928	17,687	1,073	22,385	1,730
Richness (Number of Taxa)	14	1.4	18	1.3	15	1.2	23	1.0	14	0.3	9	0.9	11	0.6	15	2.0
Simpson's Diversity Index	0.80	0.02	0.70	0.03	0.71	0.03	0.82	0.02	0.79	0.002	0.82	0.01	0.84	0.01	0.74	0.02
Simpson's Evenness Index	0.45	0.04	0.24	0.03	0.31	0.03	0.29	0.02	0.34	0.01	0.59	0.01	0.56	0.04	0.28	0.04

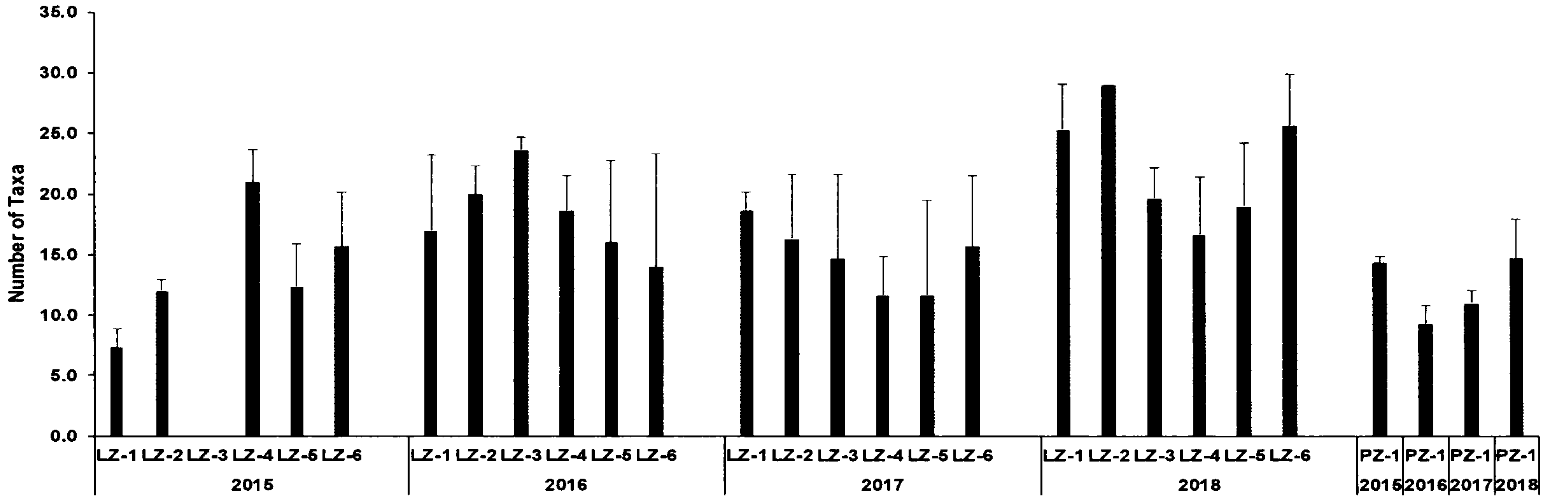
[1] Standard Error

Figure 3.37 Density of benthic invertebrates according to station in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Figure 3.38 Taxonomic richness of the benthic invertebrate community in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).

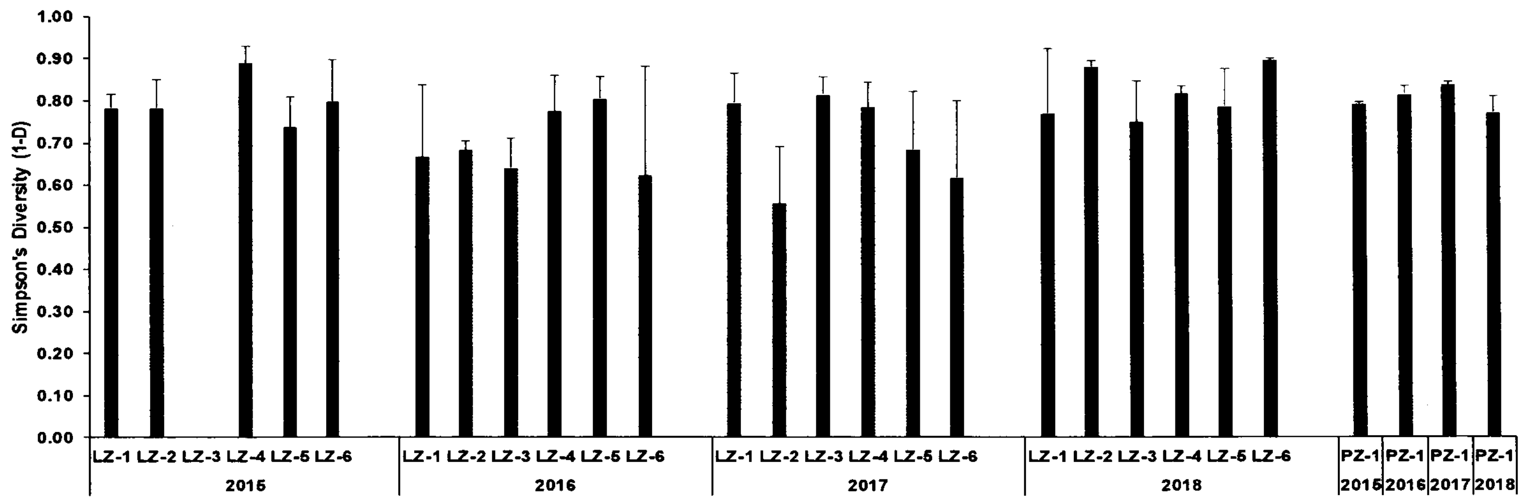


Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Table 3.10 Benthic invertebrate taxa present in No Net Loss Lake, Fort Hills Oil Sands Project, fall 2015, 2016 and 2017.

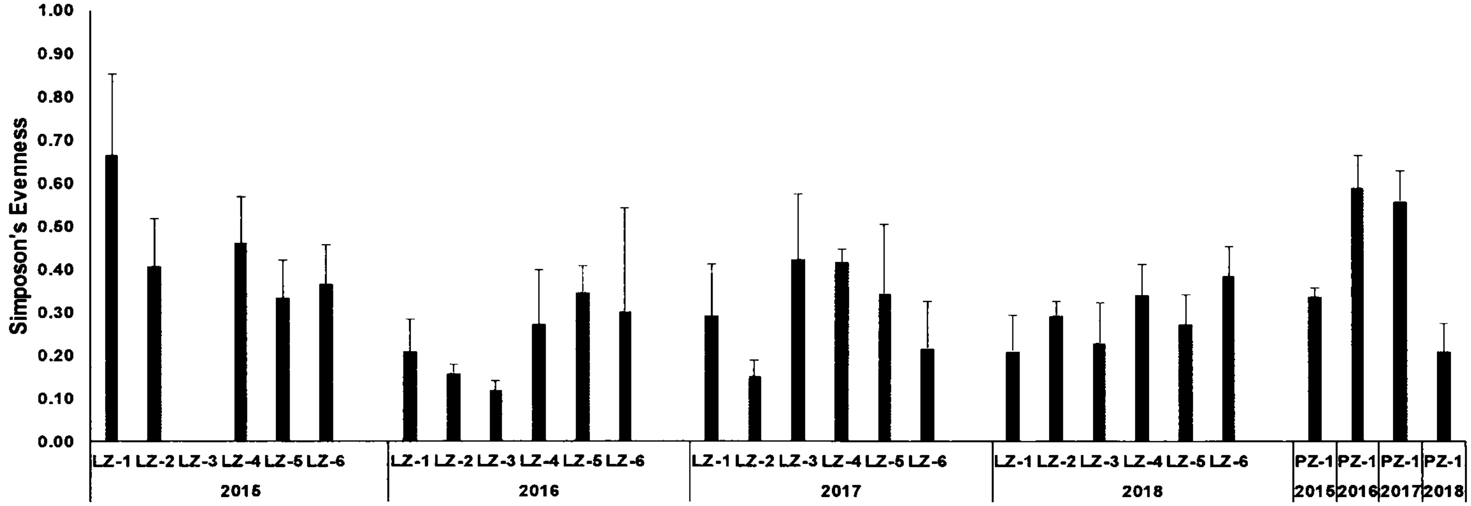
Major Taxon	Family or Higher	Littoral				Pelagic			
		2015	2016	2017	2018	2015	2016	2017	2018
Hydrozoa	Hydridae	-	X	X	-	-	-	-	-
Oligochaeta	Enchytraeidae	X	X	-	-	-	-	-	-
Oligochaeta	Lumbriculidae	-	X	-	-	-	-	-	-
Oligochaeta	Naididae	X	X	X	X	X	X	X	X
Gastropoda	Lymnaeidae	X	X	X	X	X	-	-	X
Gastropoda	Physidae	X	X	X	X	-	-	-	-
Gastropoda	Planorbidae	X	X	X	X	X	-	X	X
Gastropoda	Valvatidae	-	-	X	-	-	-	-	-
Pelecypoda	Pisidiidae	-	-	-	X	-	X	X	-
Acari – Hydracarina	-	-	X	X	X	-	-	X	-
Acari – Hydracarina	Arrenuridae	-	-	-	X	-	-	-	-
Acari – Hydracarina	Hygrobatidae	-	-	-	X	-	-	-	-
Acari – Hydracarina	Pionidae	-	-	-	X	-	-	-	-
Acari – Hydracarina	Unionicolidae	-	-	-	X	-	-	-	-
Ostracoda	-	X	X	X	X	X	X	X	X
Amphipoda	Hyalellidae	X	X	X	X	-	-	-	-
Ephemeroptera	Baetidae	X	X	X	X	X	-	-	-
Ephemeroptera	Caenidae	X	X	X	X	-	-	-	X
Ephemeroptera	Leptophlebiidae	X	X	X	X	-	-	-	-
Odonata – Anisoptera	Aeshnidae	-	-	-	X	-	-	-	-
Odonata – Anisoptera	Corduliidae	X	X	X	X	-	-	X	X
Odonata – Anisoptera	Libellulidae	-	-	X	X	-	-	-	-
Odonata – Zygoptera	Coenagrionidae	X	X	X	X	-	-	-	-
Trichoptera	Leptoceridae	X	X	X	X	-	-	-	-
Trichoptera	Hydroptilidae	-	-	X	X	-	-	-	-
Trichoptera	Molannidae	X	-	-	X	-	-	-	X
Trichoptera	Phryganeidae	-	X	X	X	-	-	-	-
Trichoptera	Polycentropodidae	X	X	X	X	-	-	-	-
Coleoptera	Dytiscidae	-	-	-	X	-	-	-	-
Coleoptera	Elmidae	-	-	-	X	-	-	-	-
Coleoptera	Haliplidae	-	X	X	X	-	-	-	-
Diptera	Ceratopogonidae	X	X	X	X	-	-	-	-
Diptera	Chaoboridae	-	-	-	-	X	X	-	-
Diptera	Tabanidae	-	-	X	X	-	-	-	-
Diptera	Chironomidae	X	X	X	X	X	X	X	X

Figure 3.39 Simpson's diversity index (1-D) of the benthic invertebrate community in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Figure 3.40 Simpson's evenness index of the benthic invertebrate community, No Net Loss Lake Fort Hills Oil Sands Project (2015 to 2018).



Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Functional feeding group classification of the benthic invertebrate community in the NNLL was similar to the structure observed in 2017 (Figure 3.43). The most dominant littoral feeding group continued to be gathering collectors with a mean of 63%. Gathering collectors are often the dominant feeding group in benthic invertebrate communities as it typically consists of dominant taxa such as select Chironomidae, Ostracoda, and Oligochaetes. Gathering taxa which feed on fine organic particles (>1 mm) are highly mobile in fine sediment such as silt and scavenge the lake bottom for food resources (Wallace and Webster 1996). Once consumed, the role of gathering collectors in the aquatic ecosystem provide re-suspension of nutrients into the lake.

Similar to 2017, filtering collectors (i.e., taxa that capture food particles from the water column) remained as the second dominant feeding group and demonstrated a slight increase in both the littoral and pelagic stations comprising 19% and 30% of the community, respectively. Increased abundance of filter feeding taxa likely corresponds to the high abundance of filtering Chironomidae taxa (i.e., Tanytarsini and Chironomini) in both sampling areas.

Scrapers remained similar to 2017 with a mean littoral percentage of 2%. Scrapers, which commonly include gastropods (snails) and select ETO taxa generally feed on algae from surfaces such as bottom substrate or vegetation. The abundance of aquatic macrophytes, which may support additional algae or biofilm growth provides a primary food resource.

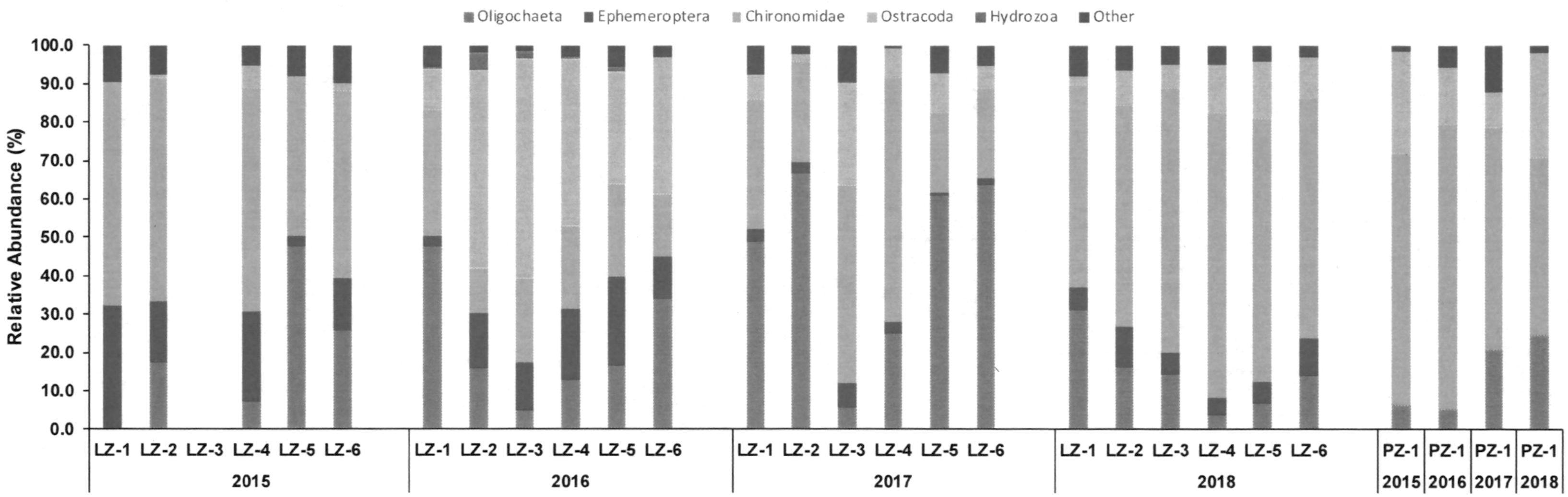
The shredder group, which breaks down leaf litter and other organic matter, showed an increase from 2017 to 6% in littoral areas. Shredder abundance in 2018 was led largely by the number of Chironomini identified across littoral stations and the pelagic station. The overall low abundance of shredders may reflect low inputs of leaf litter or other organic matter such as woody debris from the terrestrial environment at sampling locations.

The predacious feeding group demonstrated an increase in abundance in 2018 (11%) compared to 2017 (8%) in the littoral zone; however, decreased from 13% to 8% in the pelagic zone.

In summary, the most notable change in the benthic community observed in 2018 was the substantial decrease in the Naididae (worm) in the littoral stations (45% to 14%) and the increase in the Chironomidae (midges) population. Additional sampling in 2019 will provide further insight into the population structure of benthic invertebrate communities of the NNLL.

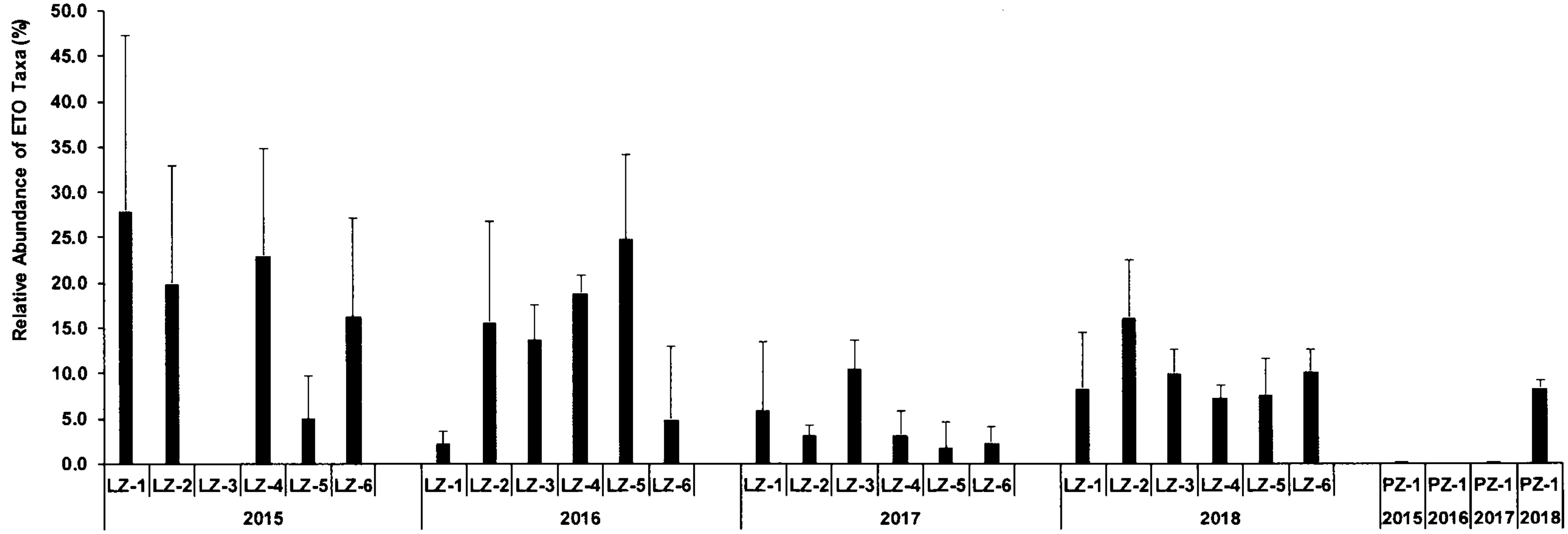
Overall benthic invertebrate density increased in 2018 compared to 2017. Benthic invertebrate metrics (i.e., abundance, richness, diversity and evenness) within the NNLL are similar to other lakes in the region (e.g., Shipyard Lake, Isadore's Lake, Kearl Lake; JOSMP 2016), including the proportions of dominant taxa, indicating that the NNLL provides a lower trophic structure important for supporting fish populations. The level of abundance, richness and relative abundance of ETO taxa suggests that the lake is progressing towards an increasingly productive lake ecosystem.

Figure 3.41 Relative abundance of dominant taxonomic groups of the benthic invertebrate community in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



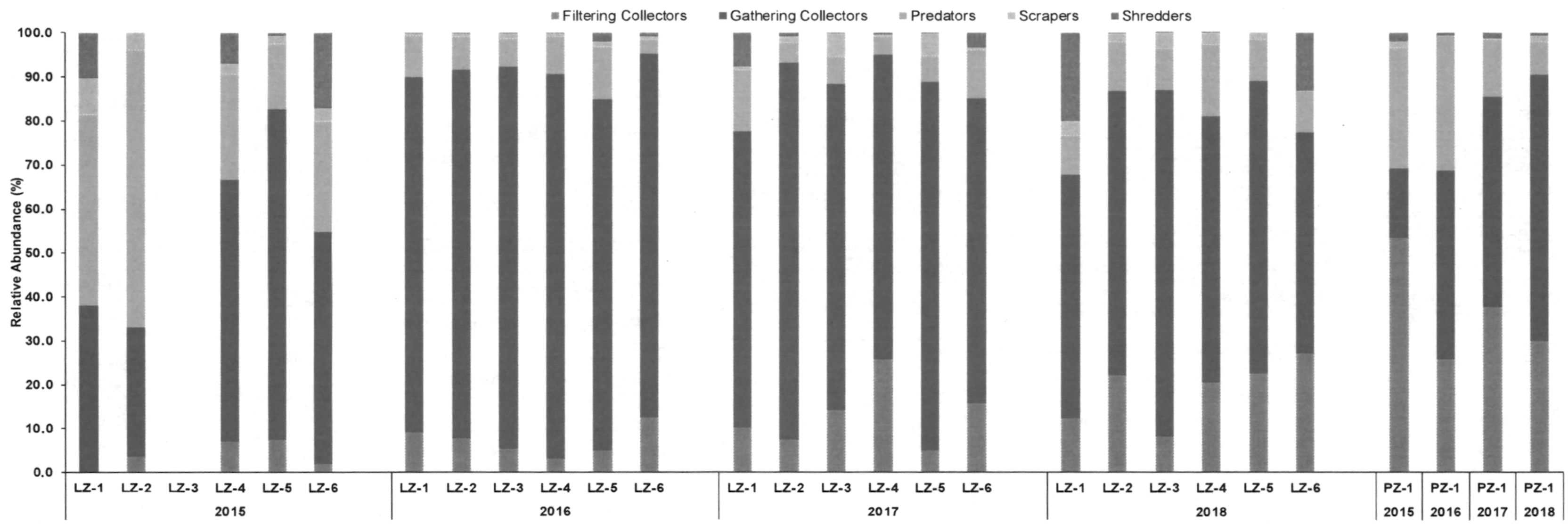
Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Figure 3.42 Relative abundance of ETO taxa within the benthic invertebrate community in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

Figure 3.43 Functional feeding group composition of the benthic invertebrate community in No Net Loss Lake, Fort Hills Oil Sands Project (2015 to 2018).



Note: LZ-3 was not sampled in 2015 due to heavy macrophyte cover.

3.4.2 Sediment Quality

Concentrations of key sediment quality variables measured in the NNLL are provided in Table 3.11. Physical properties per sampling station are provided in Table 3.12. Raw sediment quality data are provided in Appendix A3.

Sediment quality in the NNLL was generally similar to previous years. Concentrations of heavy-molecular weight F3 (C16-C34) and F4 (C34-C50) hydrocarbons decreased in the pelagic zone but increased in the littoral zone compared to 2017; however, still within historical ranges. Similar to previous years Fraction 3 hydrocarbons exceeded the guideline for Tier 1 levels of residential/parkland coarse (median grain size >75 µm) surface soils (CCME 2008) in the pelagic zone. Exceedances of Fraction 3 hydrocarbons have also been frequently observed in other lakes (e.g., McClelland Lake, Shipyard Lake, Isadore's Lake, and Kearl Lake) in the region (JOSMP 2016). All other variables measured in 2018 did not exceed relevant sediment quality guidelines for the protection of aquatic life (GoA 2018).

3.4.2.1 Sublethal Toxicity Testing of Sediment

Results of the 14-day static toxicity test for survival and growth of a freshwater amphipod (*Hyalella azteca*) and the ten-day static toxicity test for survival and growth of larvae of a freshwater midge (*Chironomus dilutes*) exposed to sediment from the NNLL are presented in Figure 3.11 and Figure 3.44. Survival of both freshwater amphipods and midges in sediment from the littoral zone and midges in the pelagic zone was noticeably lower than laboratory controls (i.e., a statistically significant decrease); however, survival of amphipods in the pelagic zone was similar to laboratory controls. Despite the decrease in amphipod and midge survival, growth of both species was higher than the laboratory controls. This is not unexpected because with fewer test organisms, there will be more to consume per organism in the test sediment; however, in general, the threshold for sublethal toxicity (e.g., growth impairment) would be expected at a lower level of exposure/impact than lethality, so if this were a toxic effect of a contaminant in the test sediment, we would also expect to see impaired growth, and this was not the case. Further, results of sediment chemistry and the increased proportion of amphipods and midges in the NNLL compared to previous years suggest that there is no inhibitory effect.

Table 3.11 Concentrations of key sediment quality variables in No Net Loss Lake, Fort Hills Oil Sands Project, September 2015 – 2018.

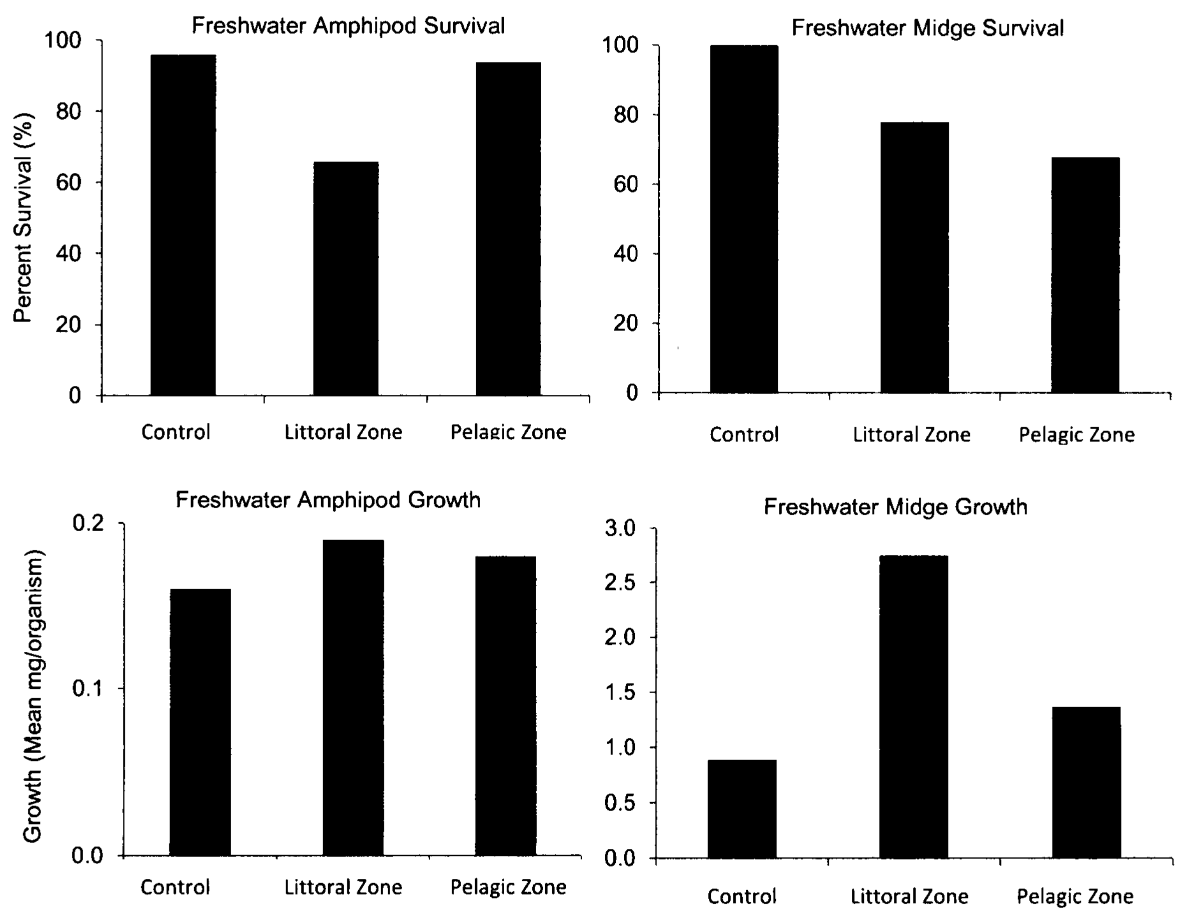
Key Variable	Units	Guideline	Littoral Zone				Pelagic Zone			
			2015	2016	2017	2018	2015	2016	2017	2018
Physical variables										
Clay	%	-	20	8	10	10	24	21	17	14
Silt	%	-	30	16	29	46	35	42	52	45
Sand	%	-	50	76	61	45	41	36	31	41
Total organic carbon	%	-	2.65	2.34	3.50	4.46	8.39	7.25	8.19	7.76
Total hydrocarbons										
BTEX	mg/kg	-	<20.0	<20.0	<24.0	<33	<30.0	<20.0	<34	<33
Fraction 1 (C6-C10)	mg/kg	-	<20.0	<20.0	<24.0	<33	<30.0	<20.0	<34	<33
Fraction 2 (C10-C16)	mg/kg	-	<20.0	21	<25.0	<25	<40.0	40	53	34
Fraction 3 (C16-C34)	mg/kg	-	199	350	126	246	598	692	657	644
Fraction 4 (C34-C50)	mg/kg	-	145	252	88	164	491	567	512	499
Polycyclic Aromatic Hydrocarbons (PAHs)										
Naphthalene	mg/kg	-	<0.005	<0.005	<0.010	<0.014	<0.010	<0.005	<0.010	<0.010
Metals that exceeded CCME guidelines in 2018										
none										
Chronic toxicity										
Chironomus survival – 10d	% surviving	-	92	96	86	78	84	98	54	68
Chironomus growth – 10d	mg/organism	-	2.77	2.27	2.97	2.75	1.93	2.06	2.57	1.37
Hyalella Survival – 14d	% surviving	-	60	92	90	66	88	95	86	94
Hyalella growth – 14d	mg/organism	-	0.09	0.15	0.18	0.19	0.06	0.13	0.17	0.18

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life (GoA 2018).

Table 3.12 Physical properties of sediment at each sampling station in the No Net Loss Lake, Fort Hills Oil Sands Project, September 2018.

Physical Properties	Units	Littoral Zone						Pelagic Zone
		LZ-1	LZ-2	LZ-3	LZ-4	LZ-5	LZ-6	PZ-1
Depth	m	1.0	3.0	2.0	3.0	1.0	2.0	6.2
Texture	-	Sandy loam	Loam	Sandy loam	Silt	Silt loam	Sandy loam	Silt loam
Clay (< 2 µm)	%	9.6	14.0	9.0	9.7	5.6	10.4	17.2
Sand (2.0 mm – 0.05 mm)	%	64.0	49.0	74.0	2.1	25.0	54.0	31.2
Silt (0.05 mm – 2 µm)	%	26.4	37.0	17.0	88.2	69.4	35.6	51.6
$CaCO_3$ Equivalent	%	19.7	11.9	47.5	53.2	52.5	44.9	3.9
Inorganic Carbon	%	2.4	1.4	5.7	6.4	6.3	5.4	0.5
Total Carbon by Combustion	%	4.5	5.9	10.6	12.9	12.9	7.6	8.7
Total Organic Carbon	%	2.1	4.5	4.9	6.5	6.6	2.2	8.2

Figure 3.44 Results of sublethal toxicity testing of sediments from the No Net Loss Lake, Fort Hills Oil Sands Project, September 2018.



3.5 VEGETATION

3.5.1 Macrophyte Communities

The littoral zone of the NNLL is armored with large cobble to a depth of approximately 1.0 m to protect the shoreline from erosion (Figure 3.45). Although macrophytes have been observed to colonize this area in the past year, aquatic vegetation has established faster in areas of the lake with soft-bottom substrates (i.e., below 1.0 m depth; Figure 3.45). The littoral zone of the NNLL has been defined as the area less than or equal to 3 m in water depth. Due to the clarity of water in the lake, sunlight penetrates depths beyond 3 m (i.e., large euphotic zone); thereby, allowing macrophytes to become established at all depths of the lake. Mean percent cover in the littoral zone of the NNLL in 2018 was 68% and is comprised primarily of submergent vegetation (Table 3.13), an increase from 2017 (56%). Percent cover by macrophyte species and transect is provided in Appendix A4.

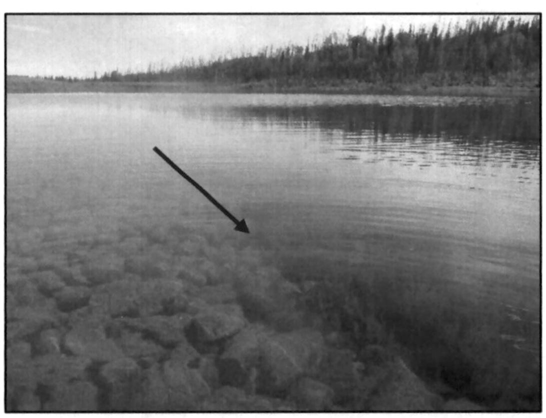
Figure 3.45 Photographs showing the macrophyte community in the No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018.



Coontail and white water-buttercup observed at LZ1.



Emergent vegetation observed at depths less than 1.0 m at LZ4.



Cobble armoring up to approximately 1.0 m depth (arrow).



Water Bur-reed becoming well established below 1.0 m depth.

Table 3.13 **Percent cover of macrophytes by type in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018.**

Percent Cover by Type	LZ-1	LZ-2	LZ-3	LZ-4	LZ-5	LZ-6	Mean	[1]SD
Submergent Vegetation	87.8	60.2	82.6	54.8	75.1	39.9	66.7	18.3
Emergent Vegetation	3.3	0.2	0.6	2.7	0.5	2.5	1.6	1.3
Inundated Vegetation	0	0.3	0.1	0.1	0.1	0.2	0.1	0.1
Total	**91**	**61**	**83**	**58**	**76**	**43**	**68**	-

[1] Standard Deviation

The mean percentage of macrophyte cover at Transect LZ1 (southwest basin) to a depth of 3.0 m was 91%, which is a large increase from 2017 observations (41%). The large increase in macrophyte cover in the littoral zone was due to the increase in density of *Ceratophyllum demersum* (coontail) at depths greater than 1.0 m. Macrophyte cover at Transect LZ2 increased to 61% to a depth of 3.0 m, representing an increase from 2017 (49%). Macrophyte cover at Transect LZ3 to a depth of 3.0 m was 83%, which is similar to cover observed in 2017 (77%). Macrophyte cover at Transect LZ4 was 58% to a depth of 3.0 m, which is similar to cover observed in 2017 (57%). Macrophyte cover at Transect LZ5 was 76% to a depth of 3.0 m, similar to what was observed in 2017 (78%). Macrophyte cover at Transect LZ6 was 43%, representing a marked increase from what was observed in 2017 (16%). This increase was mostly observed in depths greater than 1.0 m and is likely due to decreased visibility during the 2017 survey as a result of increased water turbidity due to wading.

Macrophytes provide an import source of shelter and nesting material for fish in the NNLL. The progression of the lake has shown a steady increase in macrophyte cover in the littoral zone over time. Results of the macrophyte assessment indicate that shorelines of the NNLL are stable (see Section 3.1.2.1), and bathymetry (Figure 2.5), size and functionality of the littoral and riparian zones are functioning as predicted in the NNLLDP (Golder 2006).

3.5.2 Riparian Vegetation

Reclamation planting of approximately 58,000 shrubs and trees occurred within riparian areas and the construction footprint of the NNLL in August 2015. Density and overhead cover assessments were conducted for planted species and trees and shrubs established through natural colonization in 2015, 2016 and 2017. In 2018 density of riparian vegetation was too high to accurately count stems per plot; consequently, these values were not determined. Percent overhead cover per 10 m^2 plot for the most commonly occurring species in each transect is presented in Table 3.14. Overhead cover of planted riparian vegetation and riparian vegetation that has naturally colonized the reclamation area increased in 2018, indicating the riparian area is continuing to develop around the NNLL.

Invasive weeds were not included in the assessment. White sweet-clover (*Melilotus alba*), plains wormwood (*Artemisia campestris*), sow thistle (*Sonchus arvensis*) and common tansy (*Tanacetum vulgare*) were observed within the reclamation area; however, white sweet-clover density and cover was noticeably less than what was observed in previous years and is likely attributable to the strategic application of herbicide in 2018 (Figure 3.46). It is expected that density and overhead cover of weed species will decline with natural succession of the reclamation plantings and establishment of vertical structure in the riparian environment of the NNLL (i.e., as weed species become shaded out by native shrub and tree species).

Table 3.14 Overhead cover of vegetation within the riparian zone of the No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018.

Species	LZ-1	LZ-2	LZ-3	LZ-4	LZ-5	LZ-6	2017		2018	
							Mean	[1]SD	Mean	[1]SD
Red Raspberry	11.7	36.7	50.0	58.8	43.8	43.3	13.8	7.7	46.8	16.0
Water sedge	2.0	20.0	0.0	5.0	0.0	0.0	1.7	0.6	12.5	7.8
Goldenrod	0.0	12.5	3.0	25.0	0.0	5.8	0	-	9.5	9.7
Alder	3.5	15.0	0.0	10.0	5.8	0.0	4.3	2.5	9.0	5.9
Dogwood	1.0	0.0	5.0	7.5	3.0	9.3	1.2	0.5	6.1	3.7
Spruce	0.0	0.0	3.0	2.0	2.3	3.5	1.0	0.4	2.9	1.5
Willow	1.0	2.5	1.5	3.5	3.0	2.0	0.9	0.3	2.5	0.9
Balsam Poplar	0.0	3.0	3.0	2.0	1.0	0.0	0.9	0.3	2.0	1.4

[1] Standard Deviation

Figure 3.46 Photographs showing riparian vegetation at the No Net Loss Lake, Fort Hills Oil Sands Project, July 2017 and 2018.



White sweet-sweet clover at LZ6 in 2017.



White sweet-clover at LZ6 following application of herbicide in 2018.

3.6 FISH POPULATIONS AND HABITAT

3.6.1 Fish Habitat

Fish species identified as being most suitable for inclusion in the NNLL included brook stickleback (BRST), fathead minnow (FTMN), lake chub (LKCH), longnose sucker (LNSC), northern pike (NRPK), pearl dace (PRDC), slimy sculpin (SLSC), yellow perch (YLPR), burbot (BRBT) and white sucker (WHSC) (Golder 2006). Providing fish habitat for a variety of fish species is a condition of the DFO Authorization (i.e., condition 3.3).

Suitability index (SI) values were calculated for each fish species identified for inclusion in the NNLL and the outlet channel, using habitat data collected over the course of the 2018 monitoring year. A summary of SI values and HU currently present in the NNLL and the outlet channel is presented in Table 3.15.

HU provided by the NNLL in 2018 did not change from 2017 (i.e., 865,365). An increase in macrophyte cover in the littoral zone has resulted in some habitat suitability changes, with certain species' SI values decreased (e.g., lake chub, yellow perch and longnose sucker) while others increased (e.g., brook stickleback and fathead minnow). Habitat variables in the NNLL remained relatively similar to 2017, with the exception of substrate, which showed a decrease in cobble due to settlement of fines and accumulation of organic material as macrophytes continue to colonize the littoral zone.

In the outlet channel, total HU decreased between 2017 and 2018. The main limiting habitat variable in the outlet channel is channel unit. A decrease in available pool habitat observed at the time of the survey resulted in lower SI ratings for several species in 2018 (i.e., lake chub, burbot, white sucker, brook stickleback, and fathead minnow). This reduction in available pool habitat was the result of low water levels observed in the outlet channel during the September 2018, survey, which were caused by repeated damming of the lake outlet by beavers. The reduced outlet flows caused mesohabitats previously classified as pools to be classified as run habitat during the 2018 survey. SI values in the outlet channel were rated as average or above average for all species except northern pike and yellow perch, which were classified as none and below average, respectively. The main limiting habitat variable in the outlet channel is stream gradient for northern pike and water temperature during midsummer for yellow perch (Table 3.15).

As of 2018, the NNLL and outlet channel are collectively providing 903,540 HU, which is a small decrease from 2017 (913,215 HU) but still greater than both the 869,778 HUs predicted in the NNLLDP (Golder 2006) and the 2:1 compensation ratio specified in the DFO Authorization. An evaluation of HU in the inlet channel (i.e., Creek A) is not conducted or required as part of this monitoring program. Fish habitat data collected in the inlet and outlet channels, including calculations of lacustrine and riverine HSI values for each species, are provided in Appendix A5.

Table 3.15 Summary of suitability index ratings and habitat units available in the No Net Loss Lake and outlet channel in 2018, Fort Hills Oil Sands Project.

Species	Suitability Index	Suitability Index Rating	Limiting Variable	Habitat Units
No Net Loss Lake				
Lake Chub	0.50	Average	Percent cover within littoral areas	77,127
Burbot	0.25	Below Average	Summer average maximum temperature	38,564
White Sucker	0.67	Above Average	Average of mean weekly water temperatures during July and August (for fry)	103,350
Northern Pike	0.75	Above Average	Ratio of spawning habitat to summer habitat	115,691
Yellow Perch	0.60	Average	Percent cover within littoral areas	92,552
Longnose Sucker	0.93	Excellent	Maximum Depth	143,456
Pearl Dace	0.50	Average	Percent littoral zone cover	77,127
Brook Stickleback	0.58	Average	Depth	89,467
Fathead Minnow	0.58	Average	Depth	89,467
Slimy Sculpin	0.25	Below Average	Percent cover as suitable substrate	38,564
			Subtotal	**865,365 HU**
Outlet Channel				
Lake Chub	0.80	Above Average	Channel unit	6,000
Burbot	0.41	Average	Channel unit	3,075
White Sucker	0.51	Average	Percent pools during average summer flows	3,825
Northern Pike	0	None	Stream gradient	0
Yellow Perch	0.20	Below Average	Most suitable water temperature during midsummer	1,500
Longnose sucker	1.00	Excellent	None	7,500
Pearl Dace	0.55	Average	Instream Cover	4,125
Brook Stickleback	0.41	Average	Channel unit	3,075
Fathead Minnow	0.56	Average	Channel unit	4,200
Slimy Sculpin	0.65	Average	Instream Cover	4,875
			Subtotal	**38,175 HU**
			Total	**903,540 HU**

3.6.2 Fish Populations

3.6.2.1 No Net Loss Lake

Fish populations were assessed in No Net Loss Lake from August 13 to 16, 2018 (Figure 3.47). Fork length and weight of each fish captured during the 2018 monitoring program are provided in Appendix A5. A total of five species were captured during the fish sampling program, including 49 northern pike, 106 yellow perch, four emerald shiner (EMSH), one burbot and 221 spottail shiner (SPSH). Total captures of all species combined were lower than 2017, but above the abundances observed in 2015 and 2016 (Table 3.16). White sucker and finescale dace (FNDC) were the only species captured in previous years (i.e., one finescale dace in 2017 and two white suckers in 2016) that were not captured in 2018.

A variety of gear types were deployed to maximize capture success, including hoop nets, a boat electrofisher, minnow traps, gillnets, a seine net, and angling. The majority of fish were captured in the littoral zone, with pelagic captures limited to 13 northern pike and 20 yellow perch. Similar to previous years, seine netting and boat electrofishing generated the highest CPUE in 2018. With the exception of seine netting and angling, all gear types generated higher CPUEs when compared to 2017 (Table 3.17). Seine netting CPUE decreased as a result of fewer spottail shiners being captured in 2018 while angling CPUE decreased slightly due to fewer northern pike captures by this gear type (more northern pike were captured by boat electrofishing, gill netting and hoop netting in 2018). With the exception of seine netting, GPUE increased for all gear types in 2018 compared to previous years. Most notably GPUE increased for boat electrofishing, hoop netting and gill netting due to an increase in northern pike captures (Table 3.18).

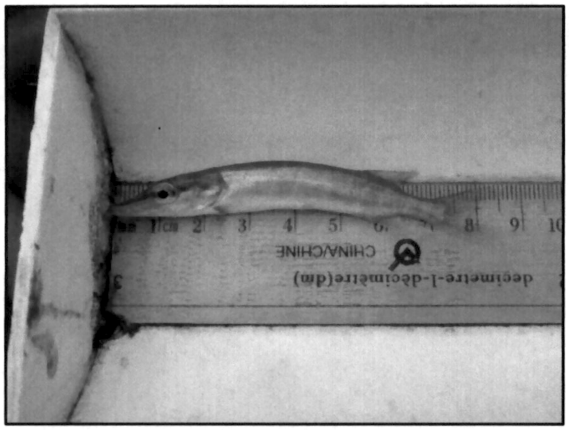
The overall decline in fish abundance is primarily due to the decrease in spottail shiners captured in 2018. Variability in capture success is not uncommon with a schooling species such as spottail shiner, as they typically congregate together in the day and disperse in the evening when predation pressure is less (Nursall 1973). Another consideration for the decrease in spottail shiners is the change in predator population structure (i.e., yellow perch and northern pike) observed in 2018. Yellow perch are also known to school, and immature perch (fork length 30 mm to 110 mm) are documented to aggregate in shallow water with spottail shiners (Nursall 1973). Yellow perch larger than 110 mm will leave the aggregation and prey on spottail shiners from below (Nursall 1973), as their diet shifts from zooplankton and benthic invertebrates to small fish (Brown et al. 2009). The majority of yellow perch captured in 2017 were immature (fork length < 80 mm) relative to 2018, which showed an increase in the number of adult perch captured in the NNLL (Figure 3.48), and suggests an increase in piscivorous yellow perch. Similarly, there was an increase in abundance of larger northern pike captured in 2018 (Figure 3.49). This increase in predation pressure is likely contributing to the decline of spottail shiners as yellow perch and northern pike become more established in the NNLL. The continued establishment of littoral predators such as yellow perch and northern pike may also limit the colonization of other cyprinids (minnows) less adapted to predation, such as lake chub, which prefer smaller headwater lakes with abundant cover and the absence of piscivorous fishes (Stasiak 2006).

Spottail shiner appear to have multiple age classes with immature (<50 mm) and adult (>59 mm) fish present (Figure 3.48). Likewise, yellow perch have multiple age classes present with immature (<80 mm) and adult (>94 mm) fish present (Figure 3.48). Northern pike were present in at least three distinct age cohorts (Figure 3.49). Inadequate sample sizes prevented the development of length-frequency distributions for other species captured in the NNLL.

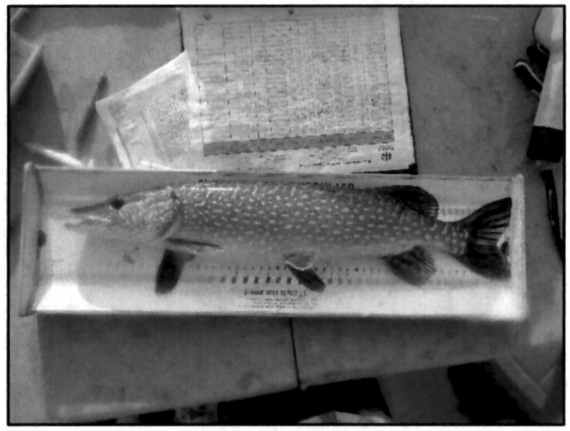
In 2018, aging structures were collected from 36 northern pike, one burbot and three yellow perch (>150 mm). The age of pike measured from anal fin rays ranged from yearlings to five years and generally increased with fork length (Table 3.19). This pattern is supported by secondary ageing structures (scales) collected from northern pike and yellow perch in 2018. A larger number of older northern pike and yellow perch were captured in the NNLL in 2018, which is further supported by the length-frequency distributions of these species (Figure 3.48 and Figure 3.49).

PIT tags were inserted into 34 northern pike, three yellow perch, and one burbot in an effort to monitor fish migration between the Athabasca River, the outlet channel, and the NNLL (Table 3.19).

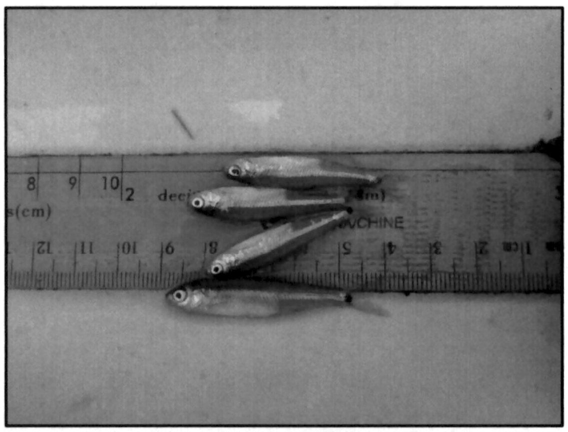
Figure 3.47 Photographs of fish species caught in the No Net Loss Lake, Fort Hills Oil Sands Project, August 2018.



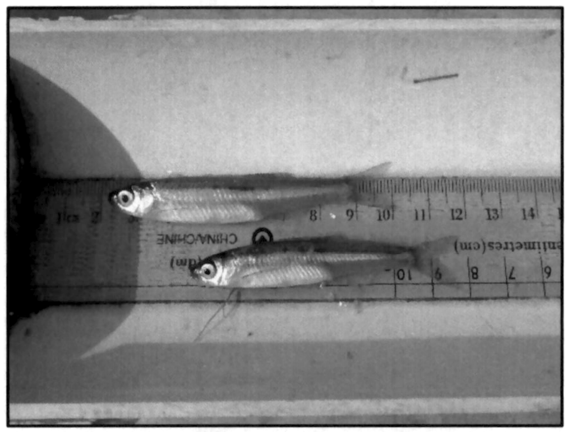
Juvenile northern pike captured by minnow trap in the littoral zone



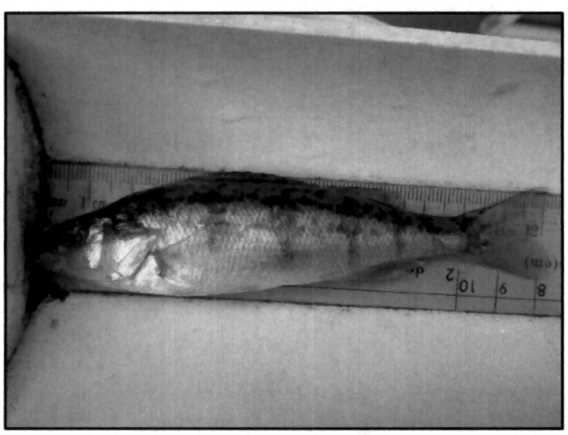
Adult northern pike captured in the pelagic zone



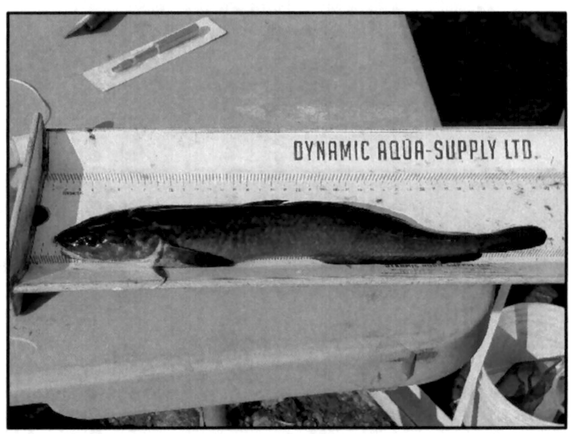
Spottail shiners captured in the littoral zone



Emerald shiners captured in the littoral zone



Yellow perch captured in the pelagic zone

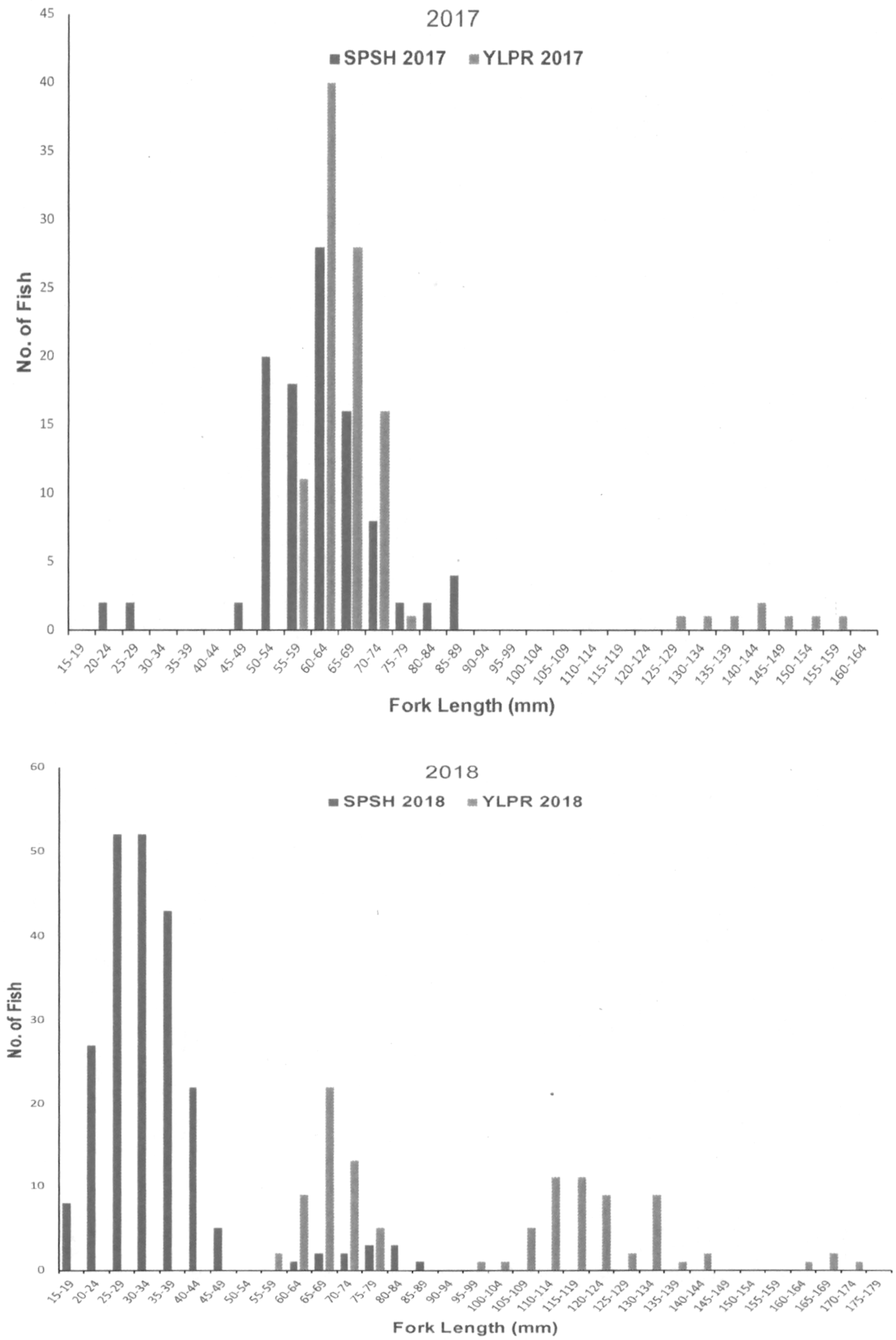


Burbot captured in the littoral zone

Table 3.16 Fish species captured by year in the No Net Loss Lake, Fort Hills Oil Sands Project, 2015 to 2018.

Species	2015	2016	2017	2018
BURB	1	0	1	1
EMSH	0	5	2	4
FNDC	0	0	1	0
NRPK	13	7	22	49
SPSH	1	96	1,228	221
WHSC	0	2	0	0
YLPR	0	1	199	106
Total	15	111	1453	381

Figure 3.48 Length-frequency histograms for spottail shiner and yellow perch captured in the No Net Loss Lake, Fort Hills Oil Sands Project, August 2017 and 2018.



Note: Only the first 100 SPSH were measured in 2017, all SPSH were measured in 2018.

Figure 3.49 Length-frequency histogram for northern pike captured in the No Net Loss Lake, Fort Hills Oil Sands Project, August 2017 and 2018.

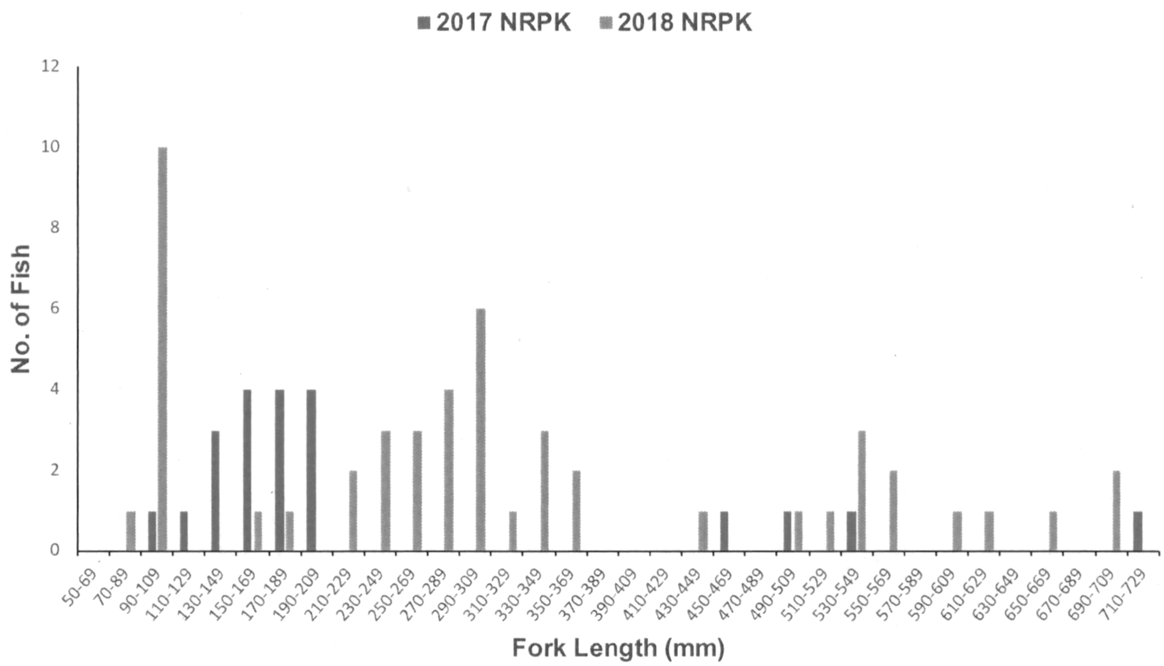


Table 3.17 **Catch-per-unit-effort (CPUE) of fish species captured by gear type and CPUE by year in No Net Loss Lake, Fort Hills Oil Sands Project, August 2015 to 2018.**

Gear Type	2018 CPUE/Species						CPUE/Year			
	Effort	Burbot	Emerald Shiner	Northern Pike	Spottail Shiner	Yellow Perch	2015	2016	2017	2018
Boat EF (No. fish/100 secs)	3,553	0.03	0.00	0.31	2.76	0.82	0.05	0.31	1.66	3.91
Minnow Trap (No. fish/hr)	1,262	0.00	0.00	0.004	0.00	0.00	0.002	0.003	0.00	0.004
Seine (No. fish/pull)	18	0.00	0.22	0.56	6.83	3.11	0.28	5.06	76.10	10.70
Angling (No. fish/min)	675	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.02	0.02
Hoop Net (No. fish/hr)	196	0.00	0.00	0.05	0.00	0.01	0.01	0.02	0.02	0.06
Gill Net (No. fish/min)	480	0.00	0.00	0.004	0.00	0.04	0.002	0.003	0.01	0.05
Total CPUE		0.03	0.22	0.95	9.59	3.98	0.36	5.40	77.81	14.74
Total No. Captured		1	4	49	221	106	15	111	1453	381

Table 3.18 **Grams-per-unit-effort (GPUE) of fish species captured by gear type and GPUE by year in No Net Loss Lake, Fort Hills Oil Sands Project, August 2015 to 2018.**

Gear Type	2018 GPUE/Species						GPUE/Year			
	Effort	Burbot	Emerald Shiner	Northern Pike	Spottail Shiner	Yellow Perch	2015	2016	2017	2018
Boat EF (grams of fish/100 secs)	3,553	6.6	0.0	38.9	0.9	13.6	2.2	12.3	13.8	60.0
Minnow Trap (grams of fish/hr)	1,262	0.0	0.0	0.02	0.0	0.0	0.01	0.01	0.0	0.02
Seine (grams of fish/pull)	18	0.0	0.5	54.0	5.8	25.0	6.9	14.1	284.0	85.2
Angling (grams of fish/min)	675	0.0	0.0	17.6	0.0	0.0	20.7	0.0	16.8	17.6
Hoop Net (grams of fish/hr)	196	0.0	0.0	30.4	0.0	0.1	0.5	0.6	0.7	30.6
Gill Net (grams of fish/min)	480	0.0	0.0	6.0	0.0	1.1	0.1	2.0	0.2	7.1
Total GPUE/species		6.6	0.5	146.9	6.7	39.8	30.4	29.0	315.5	200.8

Table 3.19 Age, length, weight and tag number of fish caught in No Net Loss Lake, Fort Hills Oil Sands Project, August 2018.

Station	Fish Id	Species	Length (mm)	Weight (g)	Age (fin ray)	Tag No.
LZ2	1	BRBT	361	234	UA	989001001534363
PZ1	1[1]	NRPK	532	988	4	989001001534409
PZ1	2	NRPK	490	729	3	989001001534413
LZ2	3	NRPK	173	38	0	989001001534424
LZ4	4	NRPK	289	151	1	989001001534434
PZ1	5	NRPK	604	1,285	4	Mortality
PZ2	6	NRPK	548	1,615	4	989001001534435
PZ1	8	NRPK	273	127	1	989001001534437
PZ2	10	NRPK	555	1,268	4	989001001534392
LZ1	12	NRPK	257	195	1	989001001534346
LZ3	13	NRPK	440	554	2	989001001534456
LZ3	14	NRPK	269	110	1	989001001534318
LZ5	15	NRPK	307	199	1	989001001534441
LZ1	16	NRPK	247	108	1	989001001534400
LZ3	17	NRPK	305	181	1	989001001534380
LZ3	18	NRPK	294	163	2	989001001534454
LZ3	19	NRPK	362	324	1	989001001534365
LZ2	20	NRPK	306	169	2	989001001534373
PZ1	21	NRPK	620	1,499	3	989001001534369
PZ2	22	NRPK	546	1,262	3	989001001534404
PZ1	23	NRPK	530	1,035	3	989001001534383
PZ1	24	NRPK	522	967	3	989001001534418
LZ5	26[2]	NRPK	704	2,530	7	989001001534430
LZ5	27	NRPK	695	1,980	5	989001001534372
LZ3	28	NRPK	350	172	1	989001001534361
Lake Perimeter	29	NRPK	273	147	2	989001001534397
Lake Perimeter	30	NRPK	305	199	1	989001001534420
Lake Perimeter	31	NRPK	291	203	1	989001001554421
Lake Perimeter	32	NRPK	272	153	1	989001001534443
Lake Perimeter	33	NRPK	229	91	1	989001001534417
Lake Perimeter	34	NRPK	252	99	1	989001001534444
Lake Perimeter	35	NRPK	227	74	1	989001001534442
Lake Perimeter	36	NRPK	249	106	1	989001001534357
PZ1	37	NRPK	551	1,100	4	Mortality

[1] Fish was captured twice in 2018.

[2] Fish is a recapture from 2017. Anal fin collected in 2017, scales collected in 2018.

UA = Unavailable

Table 3.19 (Cont'd.)

Station	Fish Id	Species	Length (mm)	Weight (g)	Age (fin ray)	Tag No.
PZ1	38	NRPK	653	1,920	5	989001001534366
Island Perimeter	39	NRPK	310	202	1	989001001534439
Island Perimeter	40	NRPK	241	95	2	989001001534396
PZ2	7	YLPR	161	58	1	989001001534394
PZ2	9	YLPR	174	70	2	989001001534453
PZ2	11	YLPR	165	60	2	989001001534395

[1] Fish was captured twice in 2018.

[2] Fish is a recapture from 2017. Anal fin collected in 2017, scales collected in 2018.

UA = Unavailable

3.6.1.1 Outlet Channel and Creek A

Fish populations were assessed in Creek A and the outlet channel on September 18, 2018 (Figure 3.50). Fork length and weight of each fish captured during the 2018 monitoring program are provided in Appendix A5.

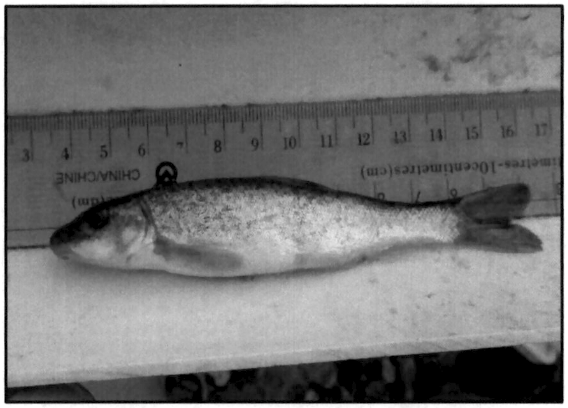
A total of five species were captured in the outlet channel during the September 2018 fish sampling program, consisting of two northern pike, five burbot, one lake chub, two longnose sucker, and one slimy sculpin; this was the lowest CPUE observed in the outlet since fish population monitoring was initiated in 2015 (Table 3.20). Species captured in previous years that were not captured in 2018 included white sucker (30 in 2016 and one in 2017), longnose dace (one in 2016), and northern redbelly dace (NRDC) (three in 2016). Species richness varied between the outlet channel stations and Creek A with a total of four species captured at station OC2, three species captured at station OC3, and similar to 2016 and 2017, no fish captured at station IC1 (Table 3.20). Relative abundance (CPUE) and biomass (GPUE) was highest at station OC3 (Table 3.21 and Table 3.22).

There was an overall decrease in CPUE compared to 2016 and 2017. As discussed in Section 3.6.1, a decrease in available pool habitat due to repeated beaver damming of the lake outlet resulted in lower SI ratings for several species (i.e., lake chub, burbot, white sucker, brook stickleback, and fathead minnow), which may also have contributed to the lower fish abundance observed in 2018. Further, the repeated building and removal of beaver dams at the lake outlet resulted in a greater range in water levels, temperatures, and DO concentrations in the outlet channel compared to previous years (Section 3.1.2.2 and Section 3.2.1.2).

In 2018, aging structures were collected from three burbot (>150 mm) captured in the outlet channel (Table 3.23). Analysis of fin rays indicated that all three burbot were one year of age irrespective of fork length (range of 158 mm to 210 mm) and weight (range of 19.0 g to 49.5 g). Inadequate sample sizes prevented the development of length-frequency distributions for fish species captured in the outlet channel.

Similar to 2016 and 2017, no fish were captured in Creek A (station IC1) in 2018. The steep gradient and high flow velocities in this section of Creek A provides marginal habitat for fish. To date only one longnose sucker has been captured in Creek A (2015). Fish captures pre-development of the NNLL were restricted to the downstream reach (i.e., within 100 m of the creek mouth). No fish were captured within upstream reaches of Creek A (i.e., upstream of the NNLL) during environmental baseline studies (TrueNorth 2001).

Figure 3.50 Photographs of fish species captured in the outlet channel, Fort Hills Oil Sands Project, September 2018.



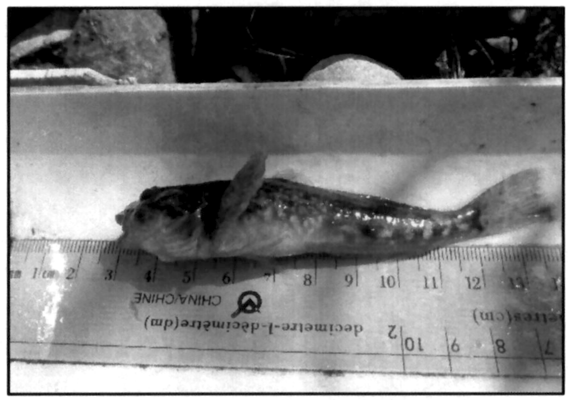
Longnose sucker captured at OC3



Lake chub captured at OC3



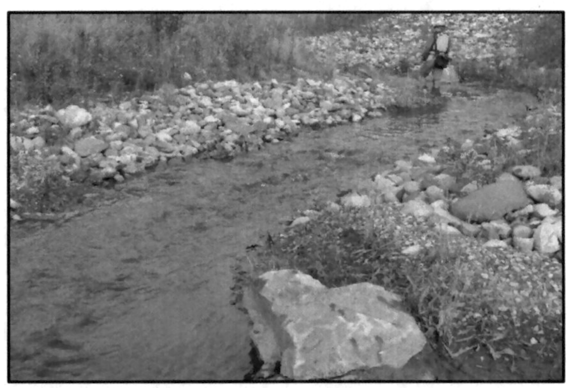
Burbot captured at OC3



Slimy sculpin captured at OC3



Run habitat in OC3. The high watermark (arrow) indicates water level prior to beaver damming



Riffle habitat in OC3

Table 3.20 Fish species captured by year in the No Net Loss Lake outlet channel, Fort Hills Oil Sands Project, 2015 to 2018.

Species	2015	2016	2017	2018
NRPK	1	0	0	2
BURB	8	5	11	5
LKCH	1	10	2	1
LNDC	0	1	0	0
LNSC	0	1	17	2
NRDC	0	3	0	0
SPSH	0	36	0	0
WHSC	0	30	1	0
SLSC	1	0	2	1
Total	11	86	33	11

Table 3.21 Total catch and catch-per-unit-effort (CPUE) of fish species captured by electrofishing in the outlet channel and Creek A, Fort Hills Oil Sands Project, 2015 to 2018.

Species	CPUE / Station											
	OC3				OC2				IC1			
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
BURB	0.44	0.27	1.09	0.35	0.18	0.38	0.21	0.17	0.00	0.00	0.00	0.00
LKCH	0.00	0.82	0.00	0.12	0.18	0.19	0.43	0.00	0.00	0.00	0.00	0.00
LNDC	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00
LNSC	0.00	0.09	1.74	0.12	0.00	0.00	0.21	0.08	0.79	0.00	0.00	0.00
NRPK	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.17	0.00	0.00	0.00	0.00
NRDC	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SPSH	0.00	0.37	0.00	0.00	0.00	6.02	0.00	0.00	0.00	0.00	0.00	0.00
SLSC	0.06	0.00	0.22	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
WHSC	0.00	2.75	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total CPUE	0.50	4.57	3.16	0.58	0.54	6.78	0.85	0.50	0.79	0.00	0.00	0.00
Effort (secs)	1,586	1,091	921	863	542	532	469	1,210	127	291	365	344
Total Fish Captured	8	50	29	5	3	36	4	6	1	0	0	0
Total No. Species	2	6	4	3	3	4	3	4	1	0	0	0

Table 3.22 Total biomass and grams-per-unit-effort (GPUE) of fish species captured by electrofishing in the outlet channel and Creek A, Fort Hills Oil Sands Project, 2015 - 2018.

Species	GPUE / Site											
	OC3				OC2				IC1			
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
BURB	11.5	10.0	20.2	9.9	9.6	15.9	13.2	3.7	0.0	0.0	0.0	0.0
LKCH	0.0	2.0	0.0	1.3	1.1	0.3	3.5	0.0	0.0	0.0	0.0	0.0
LNDC	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
LNSC	0.0	2.9	1.2	0.8	0.0	0.0	10.1	1.6	[1]-	0.0	0.0	0.0
NRPK	0.0	0.0	0.0	0.0	1.2	0.0	0.0	1.8	0.0	0.0	0.0	0.0
NRDC	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPSH	0.0	0.1	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
SLSC	0.5	0.0	4.8	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
WHSC	0.0	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total GPUE	12.0	17.1	26.3	12.0	11.9	19.9	26.8	8.2	0.0	0.0	0.0	0.0
Effort (secs)	1,586	1,091	921	863	542	532	469	1,210	127	291	365	344
Total Biomass (g)	190.6	185.6	125.3	103.5	64.7	105.5	242.5	100.2	-	0.0	0.0	0.0
Total No. Species	2	6	4	3	3	4	3	4	1	0	0	0

[1]Weight not measured

Table 3.23 Age, length, weight and tag number of fish caught in No Net Loss Lake outlet channel, Fort Hills Oil Sands Project, September 2018.

Station	Habitat Unit	Fish Id	Species	Length	Weight	Age (fin ray)	Tag No.
OC3	HU-1	1	BURB	158	19.0	1	989001001534416
OC2	HU-3	3	BURB	187	36.0	1	989001001534358
OC3	HU-3	4	BURB	210	49.5	1	989001001534297

Fish Passage

Condition 3.12 of Authorization states that the Proponent "shall ensure fish passage between the Athabasca River, the comp lake, and the reaches of the tributaries flowing into the comp lake", as specified in the NNLLDP. The outlet channel was designed to provide fish passage between the Athabasca River, the NNLL and Creek A. The outlet channel consists of a series of riffles and pools, with the pools designed to provide low-velocity resting areas for fish. This design provides water depth and velocity characteristics suitable for fish passage by northern pike and the majority of remaining sportfish species at discharges as low as 0.02 m^3/s.

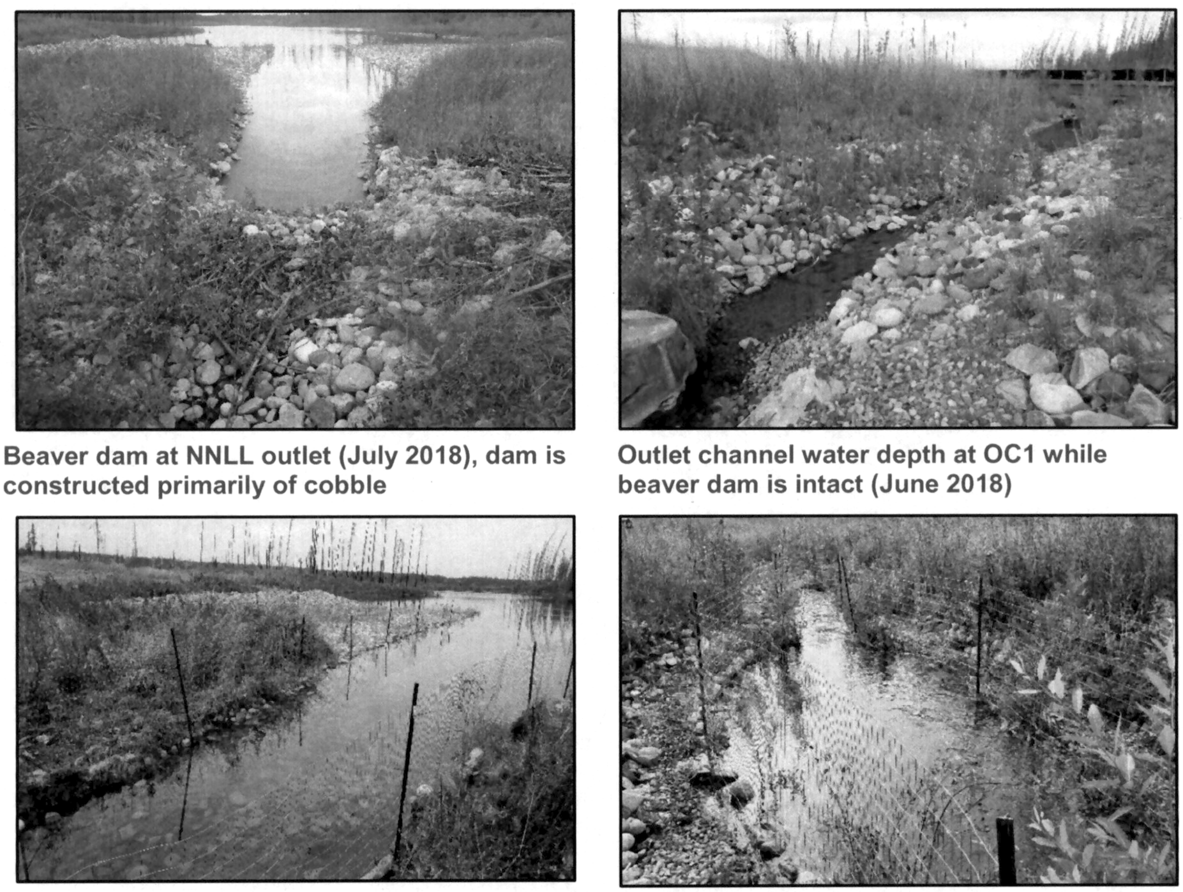
Barriers to fish migration were not observed in the outlet channel until May 2018, when beavers constructed a dam at the outlet of the NNLL, directly upstream of OC1 (Figure 3.51). A number of measures were implemented to restore fish passage and deter beaver activity in the outlet channel, including routine manual dam removal, installation of beaver fencing (Figure 3.51) and trapping (Table 3.24). The beaver fence is intended to deter beaver activity by limiting access to escape cover and local building materials while still maintaining fish passage. As part of the adaptive management process, the Proponent will continue to monitor and implement beaver deterrent measures and investigate long-term beaver management solutions to ensure fish passage between the Athabasca River, the NNLL, and Creek A is maintained; however, once the aquatic ecosystem is established to the satisfaction of DFO, beaver use of the outlet channel may need to be accepted as a naturally occurring process (Golder 2006).

There has been continuous flow in the outlet channel since hydrometric monitoring commenced in 2014; however, flows in the outlet channel have fallen below 0.02 m^3/s at certain times of the year due to responses to environmental conditions, mainly beaver damming in 2018 (Figure 3.6).

Between 2015 and 2018 there has been an increase in the number of fish caught during the fish surveys, including new species not documented in Creek A prior to the development of the NNLL. Overall, 12 species have been captured in the NNLL and outlet channel since 2015. These results, in addition to NNLL water levels remaining above the invert elevation of the outlet channel (i.e., 232.0 m; Section 3.1.2.1), and flows periodically exceeding 0.02 m^3/s for sustained periods of time are consistent with fish being able to access NNLL from the Athabasca River.

Two fish were recorded crossing the outlet channel PIT tag stations in 2018. A northern pike captured and tagged from the pelagic zone of the NNLL, was released near the NNLL outlet on August 16, 2018 and crossed ONL-01 (upstream station) on August 16, 2018 and DSO-01 (downstream station) on August 17, 2018, indicating downstream movement. A burbot captured and tagged from the OC2 study reach on September 18, 2018 was detected at DSO-01 (downstream station) on September 26, 2018, also indicating downstream movement. Two northern pike caught in the NNLL during the August 2018 fish survey were also recaptures; one was tagged during the NNLL 2017 sampling program, while the other was tagged in the NNLL two days prior to the recapture. The fork length and weigh of the recaptured northern pike tagged in 2017 was 704 mm (decrease of 14 mm from 2017) and 2,530 g (increase of 480 g from 2017), respectively. An additional 33 northern pike, one burbot, and three yellow perch were tagged in the NNLL, and three burbot were tagged in the outlet channel in 2018. It is anticipated that the PIT tag stations will provide insight into fish residence in the NNLL, and migration patterns between the Athabasca River, the outlet channel, and the NNLL as more fish are tagged over time (Table 3.25).

Figure 3.51 Photographs of the beaver dam and deterrent fencing in the outlet channel, Fort Hills Oil Sands Project, 2018.



Beaver dam at NNLL outlet (July 2018), dam is constructed primarily of cobble

Outlet channel water depth at OC1 while beaver dam is intact (June 2018)

Beaver fence at NNLL outlet (September 2018)

Beaver fence at NNLL outlet (September 2018)

Table 3.24 Schedule of beaver dam mitigation measures in the outlet channel, Fort Hills Oil Sands Project, 2018.

Date	Mitigative Measure
28-May-2018	Dam removal
3-Jun-2018	Dam removal
9-Jun-2018	Dam removal
16-Jun-2018	Dam removal
23-Jun-2018	Dam removal
28-Jun-2018	Dam removal
10-Jul-2018	Dam removal
14-Jul-2018	Dam removal
23-Jul-2018	Dam removal
28-Jul-2018	Dam removal
4-Aug-2018	Dam removal
11-Aug-2018	Dam removal
15-Aug-2018	Dam removal
7-Sep-2018	Dam removal and installation of fencing
16-Sep-2018	Dam removal
26-Sep-2018	Dam removal
26-Sep-2018	Trap three beavers
16-Oct-2018	Dam removal

Table 3.25 Number of fish tagged in the No Net Loss Lake, Creek A and outlet channel, Fort Hills Oil Sands Project, 2015 to 2018.

Species	2015	2016	2017	2018
BURB	0	0	0	4
NRPK	6	4	12	33
LNSC	1	0	1	0
WHSC	0	1	0	0
YLPR	0	0	1	3
Total	7	5	14	40

3.6.3 Fish Tissue

Muscle tissue samples were collected from 24 northern pike, one burbot and three yellow perch for analysis of methyl mercury as specified in the DFO Authorization (Condition 4.10). Methyl mercury concentrations ranged from 0.039 µg/g to 0.434 µg/g in 2018, with a mean of 0.176 µg/g (Table 3.26). Health Canada's methyl mercury guidelines for human consumption of fish are 0.50 mg/kg for general consumers (Health Canada 2007) and 0.20 mg/kg for subsistence fishers (Health Canada 1979). Accordingly, 11 fish (39% of samples) exceeded the guideline for subsistence fishers of which two were of legal retention size for recreational fishers in Alberta (>630 mm for lakes in Region NB4). Similar to previous years none exceeded the guideline for general consumers (Table 3.26). This represents an increase in fish exceeding the subsistence fishers guideline compared to 2016 and 2017 (i.e., 25% and 21%, respectively) and is expected with a larger sample size of larger and older fish. Tissue burdens of mercury are often higher in larger/older fish because mercury bioaccumulates over time (Neumann and Ward 1999). The concentration of methyl mercury in northern pike (captured in the NNLL during 2018) is positively correlated with age, length and weight (Figure 3.52). Guideline exceedances appear to be restricted to older (i.e., 3+ years) and larger fish (Figure 3.52).

A regional assessment of mercury concentrations observed in northern pike muscle samples collected from 2002 to 2013 (RAMP 2013 and Government of Alberta 2016) is compared to NNLL results in Figure 3.53. Mean mercury concentrations in northern pike were standardized to mean fork length of fish from all samples (610 mm) and compared against human consumption guidelines.

Standardized mean mercury levels from the regional assessment ranged from 0.065 mg/kg (Bitscho Lake in 2011) to 0.545 mg/kg (Hilda Lake in 2013) for the lakes sampled within the oil sands region, while lakes outside of the oil sands region, but located in northern Alberta had mean mercury levels ranging from 0.041 mg/kg (Snipe Lake in 2011) to 0.901 mg/kg (Pinehurst Lake in 2011). The mean mercury level in muscle tissue of northern pike captured from the NNLL in 2018 was 0.189 mg/kg, which was within the range of the Athabasca oil sands regional data as well as the range of other northern Alberta lakes outside of the Athabasca oil sands region (Figure 3.53).

Currently the Fish Research Licence (FRL) for the NNLL does not permit tissue sampling from fish that show evidence of previous tissue sampling. Collecting multiple samples from the same fish over time would enable assessments of methylmercury concentrations in fish from the NNLL over time (i.e., are concentrations increasing, decreasing or stable). Hatfield will engage AEP to further investigate the possibility of repeat tissue sampling in the same fish to better track mercury concentrations in fish tissue over time.

Table 3.26 Methyl mercury concentrations in fish captured in No Net Loss Lake, Fort Hills Oil Sands Project, 2018.

Station	Fish Id	Species	Length (mm)	Weight (g)	Age (Y)	Methyl Mercury Concentration (µg/g)
LZ5	27	NRPK	[1]695	1,980	5	**0.434**
PZ1	21	NRPK	620	1,500	3	**0.407**
PZ1	2	NRPK	490	729	3	**0.393**
PZ1	38	NRPK	[1]653	1,920	5	**0.344**
PZ1	5	NRPK	604	1,285	4	**0.332**
PZ1	37	NRPK	551	1,100	4	**0.330**
PZ2	6	NRPK	548	1,615	4	**0.286**
PZ1	1	NRPK	532	988	4	**0.265**
PZ2	10	NRPK	555	1,268	4	**0.252**
PZ1	24	NRPK	522	968	3	**0.248**
PZ2	22	NRPK	546	1,262	3	**0.236**
PZ1	23	NRPK	530	1,035	3	0.168
PZ1	8	NRPK	273	127	1	0.108
LZ5	15	NRPK	307	200	1	0.105
LZ1	16	NRPK	247	108	1	0.098
LZ3	14	NRPK	269	110	1	0.095
LZ3	19	NRPK	362	324	1	0.093
LZ3	13	NRPK	440	555	2	0.081
LZ1	12	NRPK	257	195	1	0.081
Lake Perimeter	33	NRPK	229	92	1	0.078
Lake Perimeter	32	NRPK	272	154	1	0.076
LZ2	3	NRPK	173	39	0	0.063
LZ4	4	NRPK	289	152	1	0.063
Lake Perimeter	31	NRPK	291	203	1	0.053
LZ2	41	BURB	361	234	UA	0.127
PZ2	11	YLPR	165	61	2	0.043
PZ2	7	YLPR	161	59	1	0.042
PZ2	9	YLPR	174	71	2	0.039

Bolded values denote exceedances of Health Canada's guideline for subsistence fisherfolk (0.20 mg/kg) (1979).

[1]Of legal size for retention by recreational fishers in Alberta (>630 mm for lakes in Region NB4).

Figure 3.52 Methyl mercury concentrations in northern pike caught in the No Net Loss Lake by length, weight and age, Fort Hills Oil Sands Project, 2018.

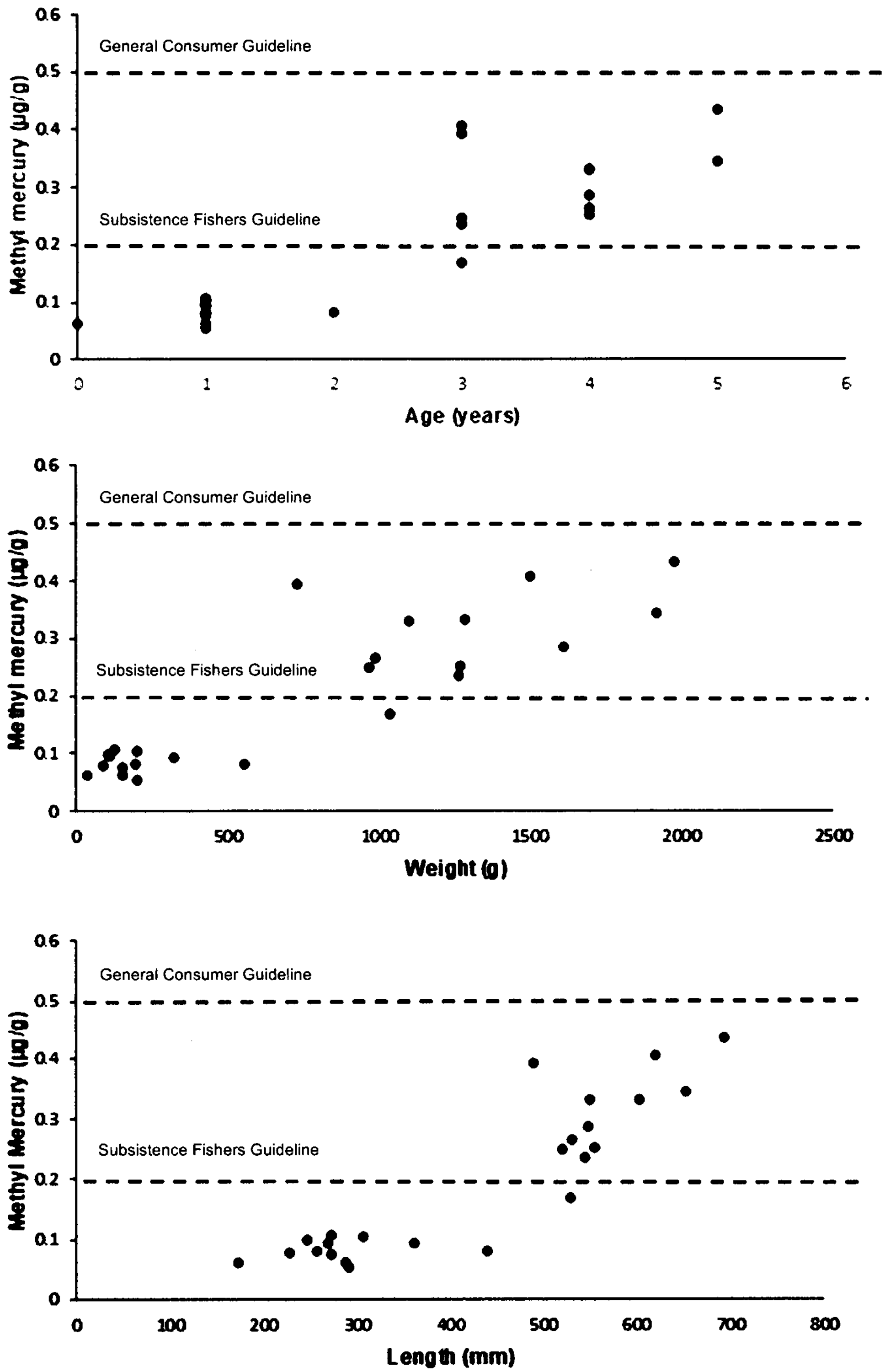
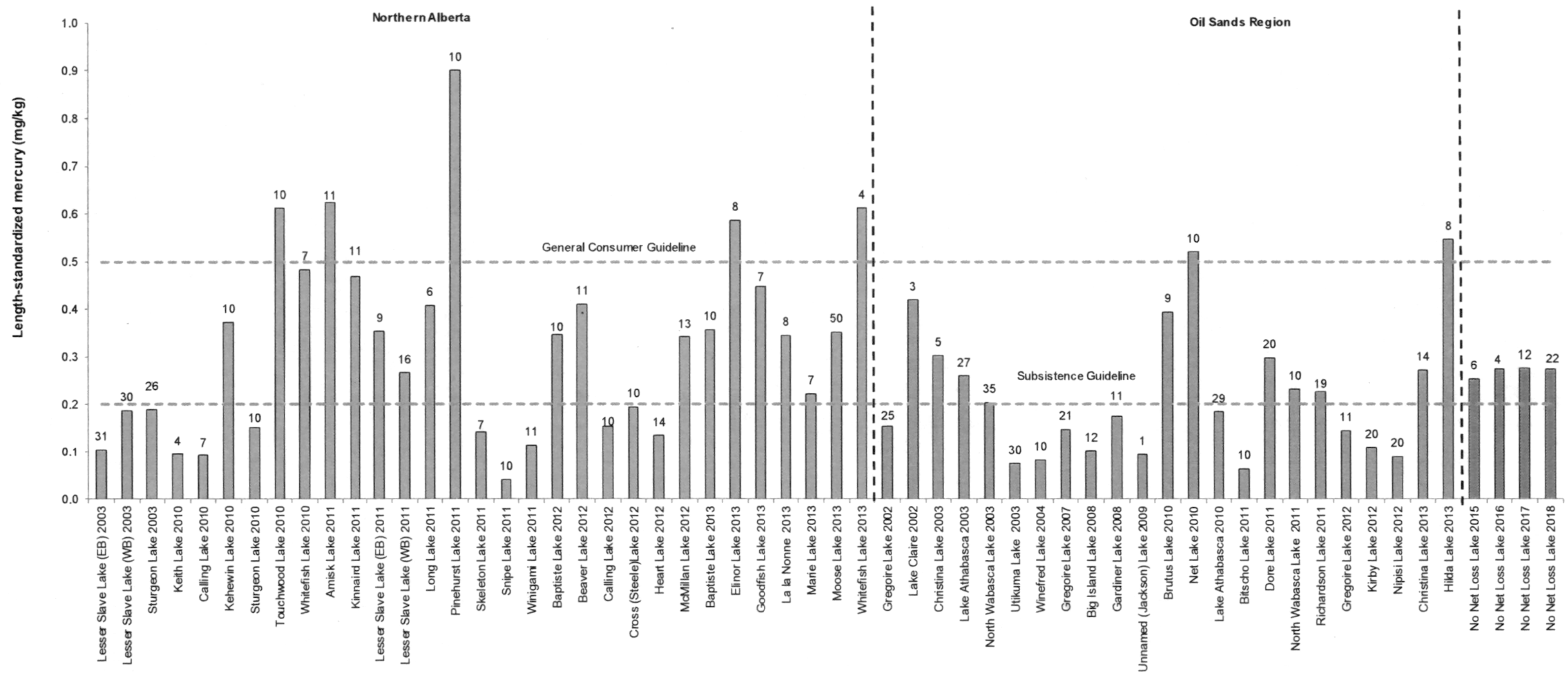


Figure 3.53 Regional comparison of mean length-standardized concentrations of mercury in northern pike from lakes in Northern Alberta and the Oil Sands Region, 2002 and 2013 compared to No Net Loss Lake 2015 to 2018 (sample size represented by number on each bar; orange bar denotes the No Net Loss Lake) (modified from RAMP 2013).



Note: 2002 to 2013 data acquired from RAMP 2013 and Government of Alberta 2016.

4.0 CONCLUSIONS

Hydrologic monitoring results in 2018 indicated that the water level of the NNLL displayed more fluctuation and was slightly higher than previous years as a result of recurring beaver dam construction and removal at the lake outlet. Evidence of shoreline erosion or disturbance to the littoral zone was not observed, indicating that the littoral zone of the NNLL was relatively stable during the open-water season. The water level of the lake was above the invert elevation of the outlet channel for the entire water year (November 1 to October 31), which allowed for continuous flow to the outlet channel from the NNLL. Similar to previous years, the NNLL water balance showed that surface water inputs exceeded surface water losses, suggesting that residual water is lost to groundwater.

Results of continuous water quality monitoring indicated that water temperature in the NNLL was influenced by both air and groundwater temperatures and is well mixed, displaying little thermal stratification. Water temperature in both Creek A and the outlet channel are primarily influenced by groundwater. Conductivity values and seasonal trends were similar to 2016 and 2017. DO concentrations in the NNLL were also similar to 2016 and 2017 values and remained within guidelines for the protection of aquatic life (GoA 2018). Under ice concentrations of DO in late winter indicated that suitable over-wintering habitat was available for fish in the NNLL. On June 19, the daily average DO concentration in the outlet channel at station OC1 (6.3 mg/L) fell below the chronic guideline for the protection of freshwater aquatic life (6.5 mg/L) and continued to fall to 5.2 mg/L (above the acute guideline of 5.0 mg/L) on June 21, until rising above chronic guidelines following removal of a beaver dam at the lake outlet on June 23. Although higher than previous years in summer, pH remained within guidelines during the open-water period. Turbidity measured in the pelagic zone remained low (i.e., maximum of 1.53 NTU) during the open-water season and was comparable to previous years. Concentrations of all water quality variables in Creek A, the outlet channel and NNLL were below water quality guidelines (GoA 2018) in 2018. Results of winter sublethal toxicity testing of water did not indicate any inhibitory effects to aquatic life in the NNLL.

Similar to previous years, results of analytical sediment quality monitoring in the NNLL showed a guideline exceedance of CCME F3 (C16-C34) hydrocarbons at the pelagic station in fall; however, concentrations of F3 (C16-C34) hydrocarbons were comparable to other lakes in the region (i.e., Shipyard, Kearl, and Isadore's lakes). Sediment hydrocarbon concentrations were dominated by F3 and F4 hydrocarbons, which indicated the presence of bitumen in sediments common for many watersheds in the Athabasca oil sands region. Survival of both freshwater amphipods and midges in sediment from the littoral zone and midges in the pelagic zone was noticeably lower than laboratory controls; however, survival of amphipods in the pelagic zone was similar to laboratory controls. Despite the decrease in amphipod and midge survival, growth of both species was higher than the laboratory controls. Further, results of sediment chemistry and the increased proportion of amphipods and midges in the NNLL compared to previous years suggest that there is no inhibitory effect.

Results of the benthic invertebrate, plankton, and macrophyte community monitoring (i.e., lower trophic levels of aquatic organisms) indicated that the productivity of the lake, as well the presence of suitable fish habitat, should support the ongoing colonization of fish populations. A number of fish species were captured in the NNLL and the outlet channel in 2018 (northern pike, yellow perch, burbot, longnose sucker, lake chub, emerald shiner, spottail shiner and slimy sculpin). Fish captured in the NNLL and the

outlet channel over the course of the monitoring program (i.e., 2015 to 2018) include: northern pike, yellow perch, burbot, longnose sucker, white sucker, lake chub, emerald shiner, spottail shiner, slimy sculpin, finescale dace, longnose dace, and northern redbelly dace. Presence of these species in the lake is consistent with ongoing fish colonization, and with upstream fish passage through the outlet channel. Similar to 2016 and 2017, no fish were captured in Creek A in 2018, as the steeper gradients and increased flow velocity provide marginal habitat for fish. To date only one longnose sucker has been captured in Creek A (2015).

Results of methyl mercury testing in fish muscle tissue in 2018 indicated that 11 of the 28 fish sampled in the NNLL exceeded the guideline for subsistence fishers, while none exceeded the guideline for general consumers. The concentration of methyl mercury in northern pike in 2018 appears positively correlated with age, length and weight as guideline exceedances appear to be restricted to older (i.e., 3+ years) and larger fish. Concentrations of mercury in fish tissue from the NNLL were within the range of the Athabasca oil sands regional dataset as well as the range of other northern Alberta lakes not influenced by oil sand activities.

Based on 2018 results, the NNLL and outlet channel are currently providing 903,540 HU, which is a small decrease from 2017 (913,215 HU), but still greater than both the 869,778 HU predicted in the NNLLDP (Golder 2006) and the 2:1 compensation ratio specified in the DFO Authorization. HU provided by the NNLL specifically in 2018 did not change from 2017 (i.e., 865,365). An increase in percent cover by macrophytes in the littoral zone has resulted in offsetting changes in habitat suitability, whereby certain species' SI values decreased (e.g., lake chub, yellow perch and longnose sucker) while SI values for other species increased (e.g., brook stickleback and fathead minnow). With the exception of substrate (i.e., decrease in cobble, as fines settle and macrophytes colonize areas <1 m deep in the littoral zone), habitat quality for other variables in the NNLL remained relatively similar to that observed in 2017. In the outlet channel, total HU decreased in 2018 compared to 2017. The main limiting habitat variable in the outlet channel is channel unit (i.e., channel morphology type). A decrease in available pool habitat resulted in lower SI ratings for several species (i.e., lake chub, burbot, white sucker, brook stickleback and fathead minnow). This reduction in available pool habitat is likely attributable to low water levels in the outlet channel during the September 2018 survey related to beaver activity (i.e., repeated damming of the lake outlet), such that mesohabitats previously identified as pools were classified in 2018 as run habitat.

Two fish were recorded crossing the outlet channel Pit Tag stations in 2018. A northern pike captured and tagged from the pelagic zone of the NNLL on August 16, 2018 crossed the upstream station on August 16, 2018, and the downstream station on August 17, 2018, suggesting downstream movement. A burbot captured and tagged from the OC2 study reach on September 18, 2018 was detected at the downstream station on September 26, 2018, also suggesting downstream movement. An additional 33 northern pike, one burbot and three yellow perch were tagged in the NNLL, and three burbot were tagged in the outlet channel in 2018. It is anticipated that the Pit Tag Antennas will provide insight into fish residence in the NNLL and migration between the Athabasca River, the outlet channel and the NNLL as more fish are tagged over time.

Overall, the productivity of the NNLL has progressed at a rate anticipated during the design and development of the NNLL (Golder 2006). The continued biological colonization of the lake indicated that the physical and chemical characteristics of the lake are capable of supporting diverse fish populations. Three changes are proposed for year five of the monitoring program:

1. Discontinue fish and fish habitat sampling in Creek A during the September (fall) program given 2018 represents the third consecutive year of no fish captures. The steeper gradient and increased flow velocity in this section of Creek A provides marginal habitat for fish, which is consistent with environmental baseline studies conducted pre-development of the NNLL when no fish were captured in this reach of Creek A. Further, the habitat characteristics remain similar year to year given the stable and consistent flow pattern of Creek A. Fish passage will continue to be monitored in order to satisfy conditions 3.12 and 3.3 of the DFO Authorization.

2. Conduct plankton monitoring in August to improve understanding of seasonal patterns of phytoplankton and zooplankton in the NNLL. 2018 represents the second consecutive year where increases in chlorophyll *a* were observed at Station PZ1 in August. Currently plankton monitoring occurs in March, May, July and September.

3. Engage AEP to further investigate the possibility of repeat tissue sampling in the same fish to better track mercury concentrations in fish tissue over time. Currently the Fish Research Licence for the NNLL does not permit tissue sampling from fish that show evidence of previous tissue sampling. Collecting multiple samples from the same fish over time would enable assessments of methylmercury concentrations in fish from the NNLL over time (i.e., are concentrations increasing, decreasing or stable).

Further evaluation will occur at the end of the approved five-year monitoring program.

5.0 REFERENCES

[AESRD] Alberta Environment and Sustainable Resource Development. 2013. Evaporation and Evapotranspiration in Alberta. Edmonton AB. April 2013. Available from: http://environment.gov.ab.ca/info/library/8938.pdf

AESRD. 2014. Environmental quality guidelines for Alberta surface waters. Water Policy Branch, Policy Division. Alberta Environment, Edmonton, AB. ISBN: 978-1-4601-1523-7 (Printed).

[BC MOE] British Columbia Ministry of Environment. 2009. Manual of British Columbia Hydrometric Standards. Version 1.0. Prepared by: Ministry of Environment Science and Information Branch for the Resources Information Standards Committee. March 2009.

Brown TG, Runciman B, Bradford MJ, Pollard S. 2009. A biological synopsis of yellow perch (*Perca flavescens*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2883: v + 28 p.

Butcher GA. 2001. Water quality criteria for aluminum. Overview report. British Columbia Ministry of Water, Land and Air Protection, Victoria, BC.

[CCME] Canadian Council of Ministers for the Environment. 2008. Canada-wide standard for petroleum hydrocarbons (PHC) in soil: scientific rationale [supporting technical document]. Winnipeg (MB): CCME. Available from: http://www.ccme.ca/assets/pdf/phc_standard_1.0_e.pdf

CCME. 2014. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment [internet]. [cited December 2016]. Available from: http://st-ts.ccme.ca/en/index.html

Colberg T, Abouguendia Z. 2000. Identification of Common Riparian Plants of Saskatchewan. Grazing and Pasture Technology Program. March 2000.

Cummins KW. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Midl. Nat. 67: 477-504.

[CEMA] Cumulative Environmental Management Association. 2009. Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region. Prepared by the Terrestrial Subgroup of CEMA. Edmonton, AB.

Delorme LD. 1989. Methods in Quaternary Ecology #7. Freshwater Ostracodes. Geoscience Canada. 16(2).

Edwards EA. 1983. Habitat suitability index models: Longnose sucker. U.S. Department of Interior. Fish and Wildlife Service. FWS/OBS-82/10.35. 21 pp.

Environment Canada. 1997. Biological Test Method: Test for Survival and Growth in Sediment Using Larvae of Freshwater Midges. December 1997. Ottawa, On.

Environment Canada. 2007. Biological Test Method: Growth Inhibition Test Using a Freshwater Alga. Report EPS 1/RM/25 Second Edition. March 2007. Ottawa, On.

Environment Canada. 2007. Biological Test Method: Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia. February 2007. Ottawa, On.

Environment Canada. 2011. Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows. February 2011. Ottawa, On.

Environment Canada. 2013. Biological Test method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod Hyalella azteca. Environmental Protection Publications, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/33.

[Golder] Golder Associates Ltd. 2006. Fort Hills Oil Sands Project No Net Loss Lake Development Plan. Volume 1 – Main Report. Prepared for: Fort Hills Energy Corporation. Prepared by: Golder Associates Ltd. September 2006.

Golder. 2008. Fish Species Habitat Suitability Index Models For the Alberta Oil Sands Region. Version 2.0. Prepared by: Golder Associates Ltd. October 2008.

Government of Alberta. 2015. Riparian rights and shoreline modifications: facts at your fingertips. Available from: www.environment.alberta.ca/03036.html

Government of Alberta. 2016. Mercury in Fish in Alberta Water Bodies 2009-2013. Edmonton (AB): Alberta Health, Health Protection Branch. Available from: http://www.health.alberta.ca/documents/Mercury-Fish-Alberta-2009-13.pdf

Government of Alberta. 2018. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta.

[Hatfield] Hatfield Consultants. 2013. Field sampling protocols manual: assessing habitat suitability in the Athabasca oil sands. North Vancouver (BC): Prepared for the Fisheries Sustainable Habitat Committee.

Hatfield. 2014. Monitoring Plan for the Fort Hills Oil Sands Project No Net Loss Lake. Prepared for: Fort Hills Energy Corporation. Prepared by: Hatfield Consultants. September 2014.

Hatfield. 2015. Field Sampling Protocols for the Fort Hills No Net Loss Lake Monitoring Program. Prepared For: Suncor Energy Operating Inc. Prepared by: Hatfield Consultants. March 31, 2015.

Hatfield. 2018. No Net Loss Lake Monitoring Program 2017 Technical Report. Prepared For: Suncor Energy Operating Inc. Prepared by: Hatfield Consultants. April 6, 2018.

Health and Welfare Canada. 1979. Methylmercury in Canada — exposure of Indian and Inuit residents to methylmercury in the Canadian environment. Ottawa (ON): Medical Services Branch, Health and Welfare Canada. 200 p.

Health Canada. 1979. Methylmercury in Canada. Exposure of Indian and Inuit Residents to Methylmercury in the Canadian Environment. Ottawa (ON): Ministry of National Health and Welfare, Medical Services Branch.

Health Canada. 2007. Canadian standards ("maximum limits") for various chemical contaminants in foods. Ottawa (ON): Health Canada. Available from: http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php

Hood JL, Roy JW, Hayashi m. 2006. Importance of groundwater in the water balance of an alpine headwater lake. Geophys. Res. Lett. 33. L13405. doi:10.1029/2006GL026611. http://onlinelibrary.wiley.com/doi.10.1029/2006GL026611/full

Inkpen W, Van Eyk R. 1998. Guide to the Common Native Trees and Shrubs of Alberta. Government of Alberta.

Inskip PD. 1982. Habitat suitability index models: Northern Pike. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10.17. 40 pp.

Johnson D, Kershaw L, Mackinnon A, Pojar J. 1995. Plants of the Western Boreal Forest & Aspen Parkland. Lone Pine Publishing and the Canadian Forest Service, Edmonton, AB.

[JOSMP] Joint Oil Sands Monitoring Plan. 2016. Regional Aquatics Monitoring in Support of the Joint Oil Sands Monitoring Plan: 2015 Program Report. Prepared for Alberta Environmental Monitoring, Evaluation and Reporting Agency by Hatfield Consultants, Kilgour and Associates Ltd., and Western Resource Solutions. April 2016.

Krieger DA, Terrell JW, and Nelson PC. 1983. Habitat suitability information: Yellow perch. Fish and Wildlife Service. FWS/OBS-83/10.55. 37 pp.

MacKay WC, Ash GR, Norris HJ (eds.). 1990. Fish Ageing Methods for Alberta. RL&L Environmental Services Ltd., in association with Alberta Fish and Wildlife Division and University of Alberta. Edmonton, AB.

Nelson JS, Paetz MJ. 1992. The Fishes of Alberta. 2nd Edition. The University of Alberta Press. Edmonton, AB.

Neumann RM, Ward SM. 1999. Bioaccumulation and biomagnification of mercury in two warmwater fish communities. J Freshwater Ecol 14:487-494 (1999)

Nursall JR. 1973. Some behavioral interactions of spottail shiners, yellow perch, and northern pike. J. fish. Res. Board Can. 30: 1161-1178

[RAMP] Regional Aquatics Monitoring Program. 2009. Regional Aquatics Monitoring Program Technical Design and Rationale. Prepared for: RAMP Steering Committee. Prepared by: Hatfield Consultants, Kilgour & Associates Ltd., and Western Resource Solutions. December 2009.

RAMP. 2013. RAMP 2012 technical report. Fort McMurray (AB): RAMP. Prepared for the RAMP Steering Committee by Hatfield Consultants; Kilgour and Associates; and Western Resource Solutions.

Royer F, Dickinson R. 2007. Plants of Alberta Trees, Shrubs, Wildflowers, Ferns, Aquatic Plants & Grasses. Lone Pine Publishing, Edmonton AB.

Stasiak R. 2006. Lake Chub (*Couesius plumbeus*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/lakechub.pdf

Suncor Energy Operating Inc.(SEOI). 2015. 2014 No Net Loss Lake Monitoring Program 35(2) Authorization AB-517-2013. Prepared by: Suncor Energy Operating Inc. April 2015.

TrueNorth Energy. 2001. Application for Approval of the Fort Hills Oil Sands Project. Volume 2: Environmental Baseline Study. Section 7: Fisheries and Fish Habitat.

Twomey KA, Nelson PC, Armour C. 1984. Habitat Suitability Index Models and Instream Flow Suitability Curves: White Sucker. U.S. Fish and Wildlife Service. Washington, DC.

[USFWS] United States Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP). U.S. Department of Interior Fish and Wildlife Service. Division of Ecological Services. ESM 102.

[USGS] United States Geological Survey. 1982. Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge. By S.E. Rantz et al. Geological Survey Water Supply Paper 2175. United States Government Printing Office, Washington.

University of Alberta. 1990. Atlas of Alberta Lakes. University of Alberta Press [Internet]. [Cited 2018 February 17]. Available from: http://albertalakes.ualberta.ca/

Wallace JB, Webster JR. 1996. The role of macroinvertebrates in stream ecosystem function. Annual Review of Entomology. 41:115-39.

[WSC] Water Survey of Canada. 2001. Hydrometric Technician Career Development Program [Internet]. [cited February 27, 2014]. Available from: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=DA898EF4-9F6C-486F-95DF-3D79109915C8

Wetzel RG. 1983. Limnology. 2nd Edition. CBS College Publishing

Wetzel RG. 2001. Limnology: lake and river ecosystems. Academic Press, San Diego, USA. ISBN-13: 978-0-12-744760-5.

Wrona FJ, Culp JM, Davies RW. 1982. Macroinvertebrate Subsampling: a simplified apparatus and approach. Can. J. Fish. Aquat. Sci. 39: 1051 – 1054.

APPENDICES

Appendix A1

Surface Water Hydrology Data

Table A1.1 Daily Surface Hydrology Data for 2018 WY.

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
1-Nov	232.343	0.048	0.071	0.162	0.274
2-Nov	232.331	0.048	0.049	0.133	0.273
3-Nov	232.323	0.048	0.037	0.118	0.317
4-Nov	232.318	0.048	0.030	0.110	0.289
5-Nov	232.316	0.048	0.026	0.108	0.279
6-Nov	232.313	0.048	0.023	0.103	0.272
7-Nov	232.311	0.048	0.021	0.101	0.273
8-Nov	232.310	0.048	0.019	0.097	0.269
9-Nov	232.308	0.049	0.018	0.095	0.277
10-Nov	232.308	0.049	0.018	0.096	0.281
11-Nov	232.307	0.049	0.018	0.096	0.275
12-Nov	232.307	0.049	0.017	0.096	0.277
13-Nov	232.307	0.049	0.017	0.096	0.259
14-Nov	232.307	0.049	0.017	0.095	0.241
15-Nov	232.306	0.048	0.016	0.093	0.224
16-Nov	232.309	0.048	0.017	0.099	0.208
17-Nov	232.309	0.048	0.017	0.097	0.207
18-Nov	232.308	0.047	0.017	0.096	0.226
19-Nov	232.307	0.048	0.017	0.096	0.244
20-Nov	232.314	0.048	0.021	0.103	0.229
21-Nov	232.311	0.048	0.019	0.100	0.166
22-Nov	232.310	0.048	0.018	0.097	0.166
23-Nov	232.310	0.048	0.019	0.101	0.205
24-Nov	232.311	0.048	0.018	0.100	0.223
25-Nov	232.310	0.048	0.017	0.098	0.239
26-Nov	-	0.048	0.017	0.097	0.260
27-Nov	-	0.048	0.023	0.106	0.268
28-Nov	232.318	0.048	0.025	0.108	0.270
29-Nov	-	0.048	0.023	0.106	0.272
30-Nov	232.314	0.048	0.020	0.104	0.274
1-Dec	232.312	0.048	0.019	0.102	0.276
2-Dec	232.309	0.048	0.017	0.100	0.277
3-Dec	232.306	0.047	0.017	0.099	0.284
4-Dec	-	0.047	0.016	0.097	0.309
5-Dec	-	0.047	0.017	0.099	0.350
6-Dec	232.301	0.047	0.016	0.098	0.354

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
7-Dec	232.300	0.048	0.016	0.098	0.354
8-Dec	232.300	0.048	0.016	0.096	0.361
9-Dec	232.300	0.048	0.016	0.097	0.349
10-Dec	232.303	0.047	0.018	0.103	0.339
11-Dec	232.305	0.048	0.019	0.105	0.331
12-Dec	232.303	0.047	0.019	0.104	0.306
13-Dec	232.301	0.047	0.018	0.102	0.282
14-Dec	232.299	0.048	0.018	0.100	-
15-Dec	232.303	0.048	0.020	0.108	-
16-Dec	232.303	0.048	0.020	0.106	0.234
17-Dec	232.301	0.048	0.020	0.105	0.235
18-Dec	232.300	0.048	0.020	0.102	0.229
19-Dec	-	0.048	0.019	0.099	0.211
20-Dec	232.297	-	0.019	0.100	0.262
21-Dec	-	-	0.019	0.101	0.280
22-Dec	-	-	0.019	0.101	0.255
23-Dec	-	-	0.020	0.098	0.246
24-Dec	-	-	0.019	0.097	0.257
25-Dec	-	-	0.019	0.095	0.268
26-Dec	-	-	0.019	0.094	0.283
27-Dec	-	-	0.019	0.095	0.290
28-Dec	-	-	0.019	0.095	0.270
29-Dec	-	-	0.019	0.092	0.255
30-Dec	-	-	0.019	0.093	0.240
31-Dec	-	-	0.020	0.088	0.173
1-Jan	-	0.045	0.020	0.089	0.175
2-Jan	-	-	0.020	0.089	0.175
3-Jan	-	0.047	0.020	0.090	0.172
4-Jan	-	0.046	0.021	0.093	0.169
5-Jan	-	0.046	0.021	0.093	0.169
6-Jan	-	0.046	0.022	0.093	0.173
7-Jan	-	0.046	0.022	0.095	0.174
8-Jan	-	0.046	0.022	0.093	0.172
9-Jan	-	0.045	0.023	0.094	0.172
10-Jan	-	0.046	0.023	0.093	0.173
11-Jan	-	0.046	0.023	0.093	0.174

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
12-Jan	-	0.045	0.023	0.091	0.176
13-Jan	-	0.045	0.023	0.091	0.194
14-Jan	-	0.045	0.023	0.090	0.206
15-Jan	-	0.046	0.023	0.089	0.216
16-Jan	-	0.045	0.024	0.090	0.224
17-Jan	-	0.045	0.024	0.090	0.228
18-Jan	-	0.045	0.025	0.091	0.226
19-Jan	-	0.045	0.026	0.094	0.219
20-Jan	-	0.046	0.027	0.096	0.217
21-Jan	-	0.045	0.027	0.096	0.216
22-Jan	-	0.047	0.028	0.097	0.210
23-Jan	-	0.045	0.028	0.099	0.200
24-Jan	-	0.045	0.028	0.098	0.194
25-Jan	-	0.044	0.028	0.095	0.193
26-Jan	-	0.045	0.028	0.093	0.182
27-Jan	-	0.044	0.028	0.090	0.170
28-Jan	-	0.044	0.028	0.088	0.164
29-Jan	-	0.045	0.028	0.088	0.161
30-Jan	-	0.044	0.029	0.091	0.155
31-Jan	-	0.044	0.029	0.090	0.150
1-Feb	232.287	0.045	0.029	0.089	0.144
2-Feb	-	0.046	0.029	0.088	0.139
3-Feb	-	0.046	0.029	0.086	0.133
4-Feb	232.285	0.046	0.029	0.088	0.128
5-Feb	232.285	0.046	0.030	0.091	0.123
6-Feb	232.285	0.046	0.030	0.091	0.119
7-Feb	232.285	0.047	0.030	0.091	0.115
8-Feb	232.284	0.047	0.030	0.094	0.112
9-Feb	232.285	0.047	0.031	0.095	0.109
10-Feb	232.286	0.047	0.031	0.096	0.107
11-Feb	232.286	0.047	0.031	0.093	0.106
12-Feb	232.287	0.045	0.030	0.094	0.106
13-Feb	232.288	0.045	0.030	0.097	0.106
14-Feb	232.289	0.045	0.031	0.096	0.105
15-Feb	232.289	0.045	0.031	0.097	0.102
16-Feb	232.290	0.046	0.031	0.096	0.099

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
17-Feb	232.289	0.046	0.030	0.097	0.096
18-Feb	232.290	0.046	0.030	0.096	0.097
19-Feb	232.290	0.046	0.030	0.096	0.102
20-Feb	232.290	0.046	0.030	0.094	0.112
21-Feb	232.290	0.046	0.031	0.096	0.124
22-Feb	232.291	0.046	0.029	0.097	0.134
23-Feb	232.292	0.047	0.030	0.098	0.142
24-Feb	232.295	0.048	0.030	0.099	0.143
25-Feb	232.301	0.049	0.030	0.100	0.137
26-Feb	232.301	0.049	0.029	0.101	0.126
27-Feb	232.303	0.049	0.029	0.102	0.110
28-Feb	232.304	0.049	0.029	0.103	0.092
1-Mar	232.302	0.048	0.028	0.104	0.074
2-Mar	232.298	0.049	0.028	0.106	0.067
3-Mar	232.296	0.049	0.028	0.109	0.070
4-Mar	232.296	0.049	0.027	0.109	0.079
5-Mar	232.295	0.050	0.027	0.110	0.087
6-Mar	232.297	0.051	0.027	0.112	0.096
7-Mar	232.296	0.051	0.026	0.111	0.121
8-Mar	232.295	0.051	0.025	0.109	0.159
9-Mar	232.295	0.052	0.025	0.108	0.185
10-Mar	232.294	0.052	0.024	0.108	0.184
11-Mar	232.294	0.053	0.024	0.109	0.163
12-Mar	232.294	0.053	0.024	0.110	0.198
13-Mar	232.295	0.053	0.024	0.112	0.208
14-Mar	232.296	0.052	0.024	0.114	0.181
15-Mar	232.300	0.051	0.026	0.117	0.188
16-Mar	232.304	0.051	0.027	0.121	0.208
17-Mar	232.306	0.052	0.028	0.122	0.169
18-Mar	232.305	0.051	0.027	0.119	0.125
19-Mar	232.305	0.050	0.026	0.117	0.129
20-Mar	232.307	0.051	0.028	0.122	0.196
21-Mar	232.306	0.050	0.027	0.118	0.184
22-Mar	232.304	0.049	0.026	0.113	0.156
23-Mar	232.306	0.048	0.026	0.114	0.179
24-Mar	232.307	0.049	0.026	0.116	0.204

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
25-Mar	232.306	0.048	0.025	0.112	0.232
26-Mar	232.307	0.048	0.025	0.111	0.262
27-Mar	232.306	0.048	0.024	0.109	0.311
28-Mar	232.306	0.048	0.024	0.106	0.376
29-Mar	232.305	0.047	0.024	0.103	0.470
30-Mar	232.305	0.048	0.024	0.101	0.577
31-Mar	232.308	0.048	0.024	0.104	0.672
1-Apr	232.312	0.049	0.024	0.107	0.779
2-Apr	232.314	0.048	0.025	0.109	0.831
3-Apr	232.315	0.048	0.025	0.109	0.901
4-Apr	232.317	0.047	0.025	0.108	1.029
5-Apr	232.318	0.046	0.026	0.109	1.183
6-Apr	232.319	0.046	0.026	0.109	1.326
7-Apr	232.320	0.046	0.025	0.111	1.545
8-Apr	232.318	0.046	0.024	0.109	1.819
9-Apr	232.316	0.046	0.024	0.109	2.427
10-Apr	232.315	0.045	0.023	0.105	3.491
11-Apr	232.316	0.045	0.023	0.103	3.440
12-Apr	232.317	0.044	0.023	0.105	2.533
13-Apr	232.321	0.044	0.024	0.107	2.888
14-Apr	232.324	0.044	0.024	0.117	4.070
15-Apr	232.329	0.045	0.026	0.129	4.741
16-Apr	232.331	0.045	0.026	0.120	5.024
17-Apr	232.330	0.045	0.026	0.122	5.359
18-Apr	232.332	0.044	0.027	0.132	5.717
19-Apr	232.335	0.044	0.028	0.147	5.854
20-Apr	232.340	0.043	0.031	0.165	4.657
21-Apr	232.345	0.043	0.033	0.169	4.795
22-Apr	232.351	0.042	0.035	0.179	5.637
23-Apr	232.353	0.041	0.035	0.176	5.683
24-Apr	232.352	0.041	0.032	0.169	5.650
25-Apr	232.350	0.040	0.030	0.156	6.653
26-Apr	232.347	0.039	0.027	0.147	6.009
27-Apr	232.345	0.039	0.025	0.136	5.658
28-Apr	232.344	0.039	0.023	0.132	6.019
29-Apr	232.343	0.038	0.022	0.129	6.422

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
30-Apr	232.342	0.038	0.019	0.116	6.841
1-May	232.344	0.038	0.017	0.109	7.195
2-May	232.349	0.037	0.005	0.078	7.602
3-May	232.359	0.040	0.004	0.076	7.922
4-May	232.369	0.041	0.004	0.076	8.419
5-May	232.379	0.041	0.003	0.075	9.483
6-May	232.389	0.042	0.003	0.075	10.057
7-May	232.398	0.041	0.003	0.076	10.322
8-May	232.407	0.040	0.003	0.075	10.480
9-May	232.413	0.040	0.003	0.075	10.512
10-May	232.421	0.039	0.003	0.075	10.380
11-May	232.428	0.040	0.004	0.077	10.172
12-May	232.435	0.041	0.004	0.079	9.844
13-May	232.440	0.042	0.004	0.078	9.388
14-May	232.447	0.042	0.003	0.078	8.866
15-May	232.454	0.042	0.003	0.079	8.379
16-May	232.458	0.042	0.004	0.079	7.926
17-May	232.462	0.042	0.004	0.079	7.436
18-May	232.467	0.042	0.004	0.078	6.946
19-May	232.472	0.042	0.003	0.078	6.498
20-May	232.476	0.042	0.004	0.079	6.113
21-May	232.481	0.042	0.004	0.079	5.767
22-May	232.486	0.042	0.003	0.077	5.422
23-May	232.489	0.042	0.003	0.076	5.034
24-May	232.494	0.042	0.003	0.076	4.650
25-May	232.499	0.042	0.003	0.076	4.265
26-May	232.505	0.042	0.003	0.077	3.970
27-May	232.507	0.042	0.003	0.076	3.736
28-May	232.499	0.042	0.046	0.262	3.513
29-May	232.451	0.042	0.035	0.180	3.226
30-May	232.446	0.042	0.004	0.067	2.974
31-May	232.450	0.042	0.002	0.063	2.743
1-Jun	232.452	0.043	0.001	0.062	2.468
2-Jun	232.456	0.042	0.001	0.062	2.244
3-Jun	232.454	0.042	0.035	0.180	2.092
4-Jun	232.429	0.043	0.022	0.113	1.965

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
5-Jun	232.433	0.045	0.012	0.080	2.042
6-Jun	232.436	0.043	0.003	0.063	2.237
7-Jun	232.443	0.043	0.002	0.060	2.289
8-Jun	232.447	0.044	0.001	0.058	2.219
9-Jun	232.444	0.045	0.037	0.176	2.119
10-Jun	232.408	0.046	0.051	0.202	1.997
11-Jun	232.397	0.047	0.011	0.075	1.933
12-Jun	232.408	0.048	0.004	0.061	1.988
13-Jun	232.424	0.048	0.002	0.059	2.179
14-Jun	232.438	0.048	0.001	0.056	2.420
15-Jun	232.445	0.047	0.001	0.053	2.479
16-Jun	232.441	0.046	0.044	0.195	2.458
17-Jun	232.415	0.045	0.020	0.089	2.390
18-Jun	232.418	0.045	0.002	0.050	2.278
19-Jun	232.422	0.045	0.001	0.048	2.124
20-Jun	232.427	0.045	0.001	0.048	1.973
21-Jun	232.431	0.045	0.001	0.047	1.808
22-Jun	232.434	0.045	0.001	0.046	1.648
23-Jun	232.438	0.046	0.024	0.111	1.598
24-Jun	232.435	0.045	0.014	0.068	1.760
25-Jun	232.438	0.045	0.003	0.047	1.743
26-Jun	232.449	0.046	0.001	0.046	1.721
27-Jun	232.461	0.047	0.004	0.052	2.094
28-Jun	232.471	0.050	0.050	0.213	3.324
29-Jun	232.463	0.049	0.022	0.100	5.310
30-Jun	232.474	0.047	0.003	0.049	6.343
1-Jul	232.483	0.046	0.001	0.045	6.914
2-Jul	232.490	0.046	0.001	0.044	7.214
3-Jul	232.501	0.046	0.002	0.050	7.824
4-Jul	232.514	0.046	0.002	0.046	9.131
5-Jul	232.519	0.045	0.001	0.043	9.527
6-Jul	232.523	0.044	0.001	0.042	9.489
7-Jul	232.526	0.044	0.001	0.043	9.574
8-Jul	232.530	0.044	0.001	0.042	9.378
9-Jul	232.532	0.044	0.001	0.042	8.949
10-Jul	232.529	0.043	0.036	0.164	8.306

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
11-Jul	232.488	0.043	0.040	0.145	7.642
12-Jul	232.481	0.043	0.005	0.048	6.869
13-Jul	232.483	0.043	0.002	0.044	6.127
14-Jul	232.476	0.043	0.039	0.147	5.400
15-Jul	232.439	0.042	0.049	0.168	4.871
16-Jul	232.427	0.042	0.006	0.050	4.518
17-Jul	232.430	0.042	0.001	0.044	4.044
18-Jul	232.431	0.042	0.001	0.042	3.607
19-Jul	232.433	0.042	0.001	0.042	3.192
20-Jul	232.434	0.042	0.001	0.041	2.811
21-Jul	232.453	0.049	0.002	0.065	2.840
22-Jul	232.496	0.046	0.009	0.070	4.096
23-Jul	232.508	0.046	0.039	0.173	5.548
24-Jul	232.467	0.045	0.069	0.261	7.531
25-Jul	232.452	0.044	0.007	0.060	9.115
26-Jul	232.457	0.043	0.003	0.050	10.174
27-Jul	232.462	0.043	0.002	0.048	10.607
28-Jul	232.458	0.043	0.037	0.148	10.373
29-Jul	232.436	0.043	0.024	0.095	9.648
30-Jul	232.433	0.042	0.002	0.053	8.677
31-Jul	232.435	0.042	0.001	0.051	7.589
1-Aug	232.438	0.042	0.001	0.051	6.905
2-Aug	232.441	0.042	0.001	0.051	6.214
3-Aug	232.444	0.042	0.001	0.052	5.549
4-Aug	232.444	0.042	0.022	0.108	4.883
5-Aug	232.428	0.042	0.014	0.079	4.271
6-Aug	232.429	0.042	0.003	0.056	3.750
7-Aug	232.432	0.042	0.001	0.055	3.283
8-Aug	232.434	0.041	0.001	0.054	3.029
9-Aug	232.435	0.041	0.001	0.054	2.779
10-Aug	232.438	0.041	0.001	0.056	2.548
11-Aug	232.434	0.041	0.024	0.123	2.343
12-Aug	232.416	0.041	0.012	0.081	2.132
13-Aug	232.416	0.041	0.002	0.059	1.888
14-Aug	232.417	0.041	0.003	0.059	1.825
15-Aug	232.418	0.041	0.015	0.101	1.635

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
16-Aug	232.400	0.040	0.030	0.155	1.535
17-Aug	232.392	0.041	0.008	0.088	1.349
18-Aug	232.393	0.041	0.003	0.078	1.196
19-Aug	232.394	0.041	0.001	0.076	1.084
20-Aug	232.397	0.041	0.001	0.076	0.989
21-Aug	232.402	0.047	0.001	0.077	0.927
22-Aug	232.406	0.045	0.002	0.077	0.866
23-Aug	232.415	0.047	0.003	0.082	0.878
24-Aug	232.422	0.048	0.004	0.082	0.935
25-Aug	232.422	0.046	0.004	0.080	0.939
26-Aug	232.424	0.047	0.004	0.080	0.917
27-Aug	232.427	0.048	0.004	0.080	0.863
28-Aug	232.430	0.048	0.005	0.083	0.809
29-Aug	232.435	0.048	0.003	0.080	0.872
30-Aug	232.446	0.052	0.005	0.095	0.991
31-Aug	232.468	0.053	0.010	0.098	1.292
1-Sep	232.474	0.051	0.007	0.089	1.493
2-Sep	232.481	0.053	0.005	0.084	1.422
3-Sep	232.491	0.047	0.005	0.083	1.302
4-Sep	232.495	0.046	0.004	0.081	1.242
5-Sep	232.497	0.048	0.004	0.081	1.214
6-Sep	232.502	0.046	0.005	0.080	1.186
7-Sep	232.495	0.046	0.038	0.192	1.166
8-Sep	232.468	0.049	0.041	0.203	1.150
9-Sep	232.462	0.050	0.038	0.189	1.457
10-Sep	232.448	0.048	0.026	0.140	1.893
11-Sep	232.447	0.048	0.010	0.094	2.142
12-Sep	232.451	0.049	0.011	0.095	2.223
13-Sep	232.454	0.049	0.006	0.085	2.406
14-Sep	232.459	0.049	0.007	0.085	2.563
15-Sep	232.462	0.049	0.007	0.086	2.617
16-Sep	232.464	0.050	0.016	0.109	2.718
17-Sep	232.453	0.050	0.027	0.137	2.792
18-Sep	232.450	0.050	0.007	0.085	2.858
19-Sep	232.455	0.050	0.006	0.080	2.882
20-Sep	232.459	0.049	0.007	0.081	2.886

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
21-Sep	232.462	0.049	0.007	0.081	2.776
22-Sep	232.465	0.049	0.007	0.079	2.728
23-Sep	232.469	0.049	0.007	0.081	2.696
24-Sep	232.473	0.049	0.007	0.082	2.638
25-Sep	232.477	0.049	0.008	0.083	-
26-Sep	232.477	0.049	0.027	0.146	-
27-Sep	232.450	0.048	0.042	0.189	-
28-Sep	232.433	0.048	0.030	0.144	-
29-Sep	232.422	0.048	0.025	0.126	-
30-Sep	232.416	0.047	0.021	0.115	-
1-Oct	232.412	0.047	0.019	0.110	-
2-Oct	232.409	0.047	0.018	0.106	-
3-Oct	232.407	0.047	0.017	0.105	-
4-Oct	232.406	0.046	0.017	0.103	-
5-Oct	232.407	0.046	0.017	0.102	-
6-Oct	232.406	0.045	0.016	0.098	-
7-Oct	232.406	0.045	0.016	0.098	-
8-Oct	232.405	0.044	0.016	0.094	-
9-Oct	232.405	0.044	0.016	0.093	-
10-Oct	232.405	0.043	0.016	0.092	-
11-Oct	232.406	0.043	0.016	0.093	-
12-Oct	232.406	0.043	0.017	0.095	-
13-Oct	232.406	0.043	0.017	0.094	-
14-Oct	232.406	0.042	0.017	0.094	-
15-Oct	232.407	0.043	0.017	0.097	-
16-Oct	232.407	0.042	0.025	0.116	-
17-Oct	-	0.042	0.030	0.130	-
18-Oct	-	0.042	0.027	0.122	-
19-Oct	-	0.041	0.024	0.114	-
20-Oct	-	0.041	0.023	0.111	-
21-Oct	-	0.041	0.022	0.108	-
22-Oct	-	0.040	0.021	0.105	-
23-Oct	-	0.040	0.020	0.104	-
24-Oct	-	0.039	0.020	0.103	-
25-Oct	-	0.039	0.019	0.102	-
26-Oct	-	0.039	0.019	0.103	-

Table A1.1 (Cont'd.)

Date	NNLL Lake Level	Creek A Discharge	Outlet Discharge	Channel Discharge	07DA008 – Muskeg River Near Fort McKay Discharge
	(m a.s.l.)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
27-Oct	-	0.038	0.019	0.103	-
28-Oct	-	0.039	0.018	0.102	-
29-Oct	-	0.039	0.018	0.103	-
30-Oct	-	0.039	0.018	0.102	-
31-Oct	-	0.039	0.018	0.099	-

Table A1.2 NNLL Daily Water Balance Data for the 2018 WY.

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
1-Nov	-2915	0	-8	4147	6134	-935
2-Nov	-1841	0	-8	4147	4234	-1762
3-Nov	-1227	0	-8	4147	3197	-2186
4-Nov	-767	0	-8	4147	2592	-2330
5-Nov	-307	0	-8	4147	2246	-2216
6-Nov	-460	0	-8	4147	1987	-2628
7-Nov	-307	0	-8	4147	1814	-2648
8-Nov	-153	0	-8	4147	1642	-2667
9-Nov	-307	0	-8	4234	1555	-2993
10-Nov	0	0	-8	4234	1555	-2686
11-Nov	-153	0	-8	4234	1555	-2840
12-Nov	0	0	-8	4234	1469	-2773
13-Nov	0	0	-8	4234	1469	-2773
14-Nov	0	0	-8	4234	1469	-2773
15-Nov	-153	261	-8	4147	1382	-3187
16-Nov	460	46	-8	4147	1469	-2272
17-Nov	0	0	-8	4147	1469	-2686
18-Nov	-153	0	-8	4061	1469	-2753
19-Nov	-153	408	-8	4147	1469	-3248
20-Nov	1074	46	-8	4147	1814	-1313
21-Nov	-460	0	-8	4147	1642	-2974
22-Nov	-153	808	-8	4147	1555	-3562
23-Nov	0	433	-8	4147	1642	-2946
24-Nov	153	0	-8	4147	1555	-2447
25-Nov	-153	8	-8	4147	1469	-2848
26-Nov	409	140	-8	4147	1469	-2417
27-Nov	409	1258	-8	4147	1987	-3017
28-Nov	409	3019	-8	4147	2160	-4605
29-Nov	-307	0	-8	4147	1987	-2475
30-Nov	-307	1302	-8	4147	1728	-4036
1-Dec	-307	425	-22	4147	1642	-3260
2-Dec	-460	0	-22	4147	1469	-3161
3-Dec	-460	0	-22	4061	1469	-3075
4-Dec	-256	133	-22	4061	1382	-3090

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
5-Dec	-256	0	-22	4061	1469	-2870
6-Dec	-256	0	-22	4061	1382	-2956
7-Dec	-153	0	-22	4147	1382	-2941
8-Dec	0	0	-22	4147	1382	-2787
9-Dec	0	32	-22	4147	1382	-2819
10-Dec	460	1796	-22	4061	1555	-3864
11-Dec	307	0	-22	4147	1642	-2221
12-Dec	-307	0	-22	4061	1642	-2748
13-Dec	-307	0	-22	4061	1555	-2835
14-Dec	-307	0	-22	4147	1555	-2921
15-Dec	614	963	-22	4147	1728	-2791
16-Dec	0	95	-22	4147	1728	-2537
17-Dec	-307	850	-22	4147	1728	-3598
18-Dec	-153	0	-22	4147	1728	-2595
19-Dec	-230	0	-22	4147	1642	-2758
20-Dec	-230	0	-22	4127	1642	-2738
21-Dec	-36	8	-22	4107	1642	-2531
22-Dec	-36	0	-22	4087	1642	-2504
23-Dec	-36	0	-22	4067	1728	-2398
24-Dec	-36	0	-22	4048	1642	-2464
25-Dec	-36	0	-22	4028	1642	-2444
26-Dec	-36	0	-22	4008	1642	-2424
27-Dec	-36	0	-22	3988	1642	-2404
28-Dec	-36	0	-22	3968	1642	-2384
29-Dec	-36	0	-22	3948	1642	-2364
30-Dec	-36	0	-22	3928	1642	-2344
31-Dec	-36	0	-22	3908	1728	-2238
1-Jan	-36	0	-1	3888	1728	-2197
2-Jan	-36	0	-1	3974	1728	-2283
3-Jan	-36	0	-1	4061	1728	-2370
4-Jan	-36	0	-1	3974	1814	-2197
5-Jan	-36	0	-1	3974	1814	-2197
6-Jan	-36	8	-1	3974	1901	-2118
7-Jan	-36	0	-1	3974	1901	-2110

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
8-Jan	-36	0	-1	3974	1901	-2110
9-Jan	-36	84	-1	3888	1987	-2022
10-Jan	-36	0	-1	3974	1987	-2024
11-Jan	-36	0	-1	3974	1987	-2024
12-Jan	-36	0	-1	3888	1987	-1938
13-Jan	-36	9	-1	3888	1987	-1947
14-Jan	-36	0	-1	3888	1987	-1938
15-Jan	-36	0	-1	3974	1987	-2024
16-Jan	-36	0	-1	3888	2074	-1851
17-Jan	-36	0	-1	3888	2074	-1851
18-Jan	-36	17	-1	3888	2160	-1782
19-Jan	-36	61	-1	3888	2246	-1740
20-Jan	-36	17	-1	3974	2333	-1695
21-Jan	-36	0	-1	3888	2333	-1592
22-Jan	-36	156	-1	4061	2419	-1835
23-Jan	-36	784	-1	3888	2419	-2289
24-Jan	-36	485	-1	3888	2419	-1990
25-Jan	-36	0	-1	3802	2419	-1419
26-Jan	-36	0	-1	3888	2419	-1506
27-Jan	-36	0	-1	3802	2419	-1419
28-Jan	-36	0	-1	3802	2419	-1419
29-Jan	-36	48	-1	3888	2419	-1553
30-Jan	-36	32	-1	3802	2506	-1365
31-Jan	-36	0	-1	3802	2506	-1333
1-Feb	-36	0	-2	3888	2506	-1420
2-Feb	-153	0	-2	3974	2506	-1624
3-Feb	0	0	-2	3974	2506	-1471
4-Feb	-153	0	-2	3974	2506	-1624
5-Feb	0	0	-2	3974	2592	-1385
6-Feb	0	0	-2	3974	2592	-1385
7-Feb	0	0	-2	4061	2592	-1471
8-Feb	-153	0	-2	4061	2592	-1624
9-Feb	153	0	-2	4061	2678	-1231
10-Feb	153	0	-2	4061	2678	-1231

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
11-Feb	0	0	-2	4061	2678	-1385
12-Feb	153	0	-2	3888	2592	-1145
13-Feb	153	0	-2	3888	2592	-1145
14-Feb	153	0	-2	3888	2678	-1058
15-Feb	0	0	-2	3888	2678	-1212
16-Feb	153	0	-2	3974	2678	-1145
17-Feb	-153	0	-2	3974	2592	-1538
18-Feb	153	0	-2	3974	2592	-1231
19-Feb	0	0	-2	3974	2592	-1385
20-Feb	0	0	-2	3974	2592	-1385
21-Feb	0	91	-2	3974	2678	-1389
22-Feb	153	0	-2	3974	2506	-1318
23-Feb	153	43	-2	4061	2592	-2997
24-Feb	460	0	-2	4147	2592	-4370
25-Feb	920	0	-2	4234	2592	-3997
26-Feb	0	0	-2	4234	2506	-3367
27-Feb	307	0	-2	4234	2506	-3878
28-Feb	153	0	-2	4234	2506	-3213
1-Mar	-307	0	30	4147	2419	-2005
2-Mar	-614	0	30	4234	2419	-2398
3-Mar	-307	0	30	4234	2419	-2091
4-Mar	0	0	30	4234	2333	-1871
5-Mar	-153	385	30	4320	2333	-2496
6-Mar	307	31	30	4406	2333	-1767
7-Mar	-153	0	30	4406	2246	-2283
8-Mar	-153	0	30	4406	2160	-2370
9-Mar	0	0	30	4493	2160	-2303
10-Mar	-153	0	30	4493	2074	-2542
11-Mar	0	0	30	4579	2074	-2475
12-Mar	0	0	30	4579	2074	-2475
13-Mar	153	0	30	4579	2074	-2322
14-Mar	153	0	30	4493	2074	-3872
15-Mar	614	0	30	4406	2246	-3153
16-Mar	614	0	30	4406	2333	-4703

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
17-Mar	307	0	30	4493	2419	-1737
18-Mar	-153	0	30	4406	2333	-2197
19-Mar	0	0	30	4320	2246	-2862
20-Mar	307	91	30	4406	2419	-1741
21-Mar	-153	0	30	4320	2333	-2110
22-Mar	-307	0	30	4234	2246	-2264
23-Mar	307	896	30	4147	2246	-2460
24-Mar	153	57	30	4234	2246	-1860
25-Mar	-153	0	30	4147	2160	-2110
26-Mar	153	416	30	4147	2160	-2219
27-Mar	-153	0	30	4147	2074	-2197
28-Mar	0	0	30	4147	2074	-2043
29-Mar	-153	0	30	4061	2074	-2110
30-Mar	0	0	30	4147	2074	-3680
31-Mar	460	0	30	4147	2074	-4856
1-Apr	614	0	296	4234	2074	-4524
2-Apr	307	0	296	4147	2160	-4658
3-Apr	153	0	296	4147	2160	-4811
4-Apr	307	0	296	4061	2160	-4571
5-Apr	153	0	296	3974	2246	-4552
6-Apr	153	0	296	3974	2246	-4552
7-Apr	153	0	296	3974	2160	-4638
8-Apr	-307	0	296	3974	2074	-1912
9-Apr	-307	0	296	3974	2074	-1912
10-Apr	-153	0	296	3888	1987	-1758
11-Apr	153	0	296	3888	1987	-3088
12-Apr	153	0	296	3802	1987	-4638
13-Apr	614	0	296	3802	2074	-4092
14-Apr	460	0	296	3802	2074	-4245
15-Apr	767	0	296	3888	2246	-579
16-Apr	307	187	296	3888	2246	-1226
17-Apr	-153	568	296	3888	2246	-2885
18-Apr	307	0	296	3802	2333	-4139
19-Apr	460	0	296	3802	2419	-626

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
20-Apr	767	0	296	3715	2678	-2429
21-Apr	767	0	296	3715	2851	-3074
22-Apr	920	74	296	3629	3024	-2735
23-Apr	307	0	296	3542	3024	84
24-Apr	-153	0	296	3542	2765	-635
25-Apr	-307	0	296	3456	2592	-875
26-Apr	-460	0	296	3370	2333	-1201
27-Apr	-307	0	296	3370	2160	-1220
28-Apr	-153	0	296	3370	1987	-1240
29-Apr	-153	44	296	3283	1901	-1284
30-Apr	-153	0	296	3283	1642	-1499
1-May	307	0	645	3283	1469	-863
2-May	767	0	645	3197	432	-1353
3-May	1534	0	645	3456	346	-931
4-May	1534	0	645	3542	346	-1018
5-May	1534	0	645	3542	259	-1104
6-May	1534	0	645	3629	259	-1191
7-May	1381	0	645	3542	259	-1258
8-May	1381	0	645	3456	259	-1171
9-May	920	0	645	3456	259	-1631
10-May	1227	0	645	3370	259	-1238
11-May	1074	0	645	3456	346	-1392
12-May	1074	0	645	3542	346	-1478
13-May	767	51	645	3629	346	-1922
14-May	1074	0	645	3629	259	-1651
15-May	1074	0	645	3629	259	-1651
16-May	614	106	645	3629	346	-2131
17-May	614	51	645	3629	346	-2075
18-May	767	0	645	3629	346	-1871
19-May	767	0	645	3629	259	-1958
20-May	614	52	645	3629	346	-2077
21-May	767	0	645	3629	346	-1871
22-May	767	0	645	3629	259	-1958
23-May	460	0	645	3629	259	-2264

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
24-May	767	0	645	3629	259	-1958
25-May	767	235	645	3629	259	-2192
26-May	920	413	645	3629	259	-2217
27-May	307	0	645	3629	259	-2418
28-May	-1227	0	645	3629	3974	-237
29-May	-7363	0	645	3629	3024	-7323
30-May	-767	0	645	3629	346	-3405
31-May	614	0	645	3629	173	-2197
1-Jun	307	37	739	3715	86	-2620
2-Jun	614	0	739	3629	86	-2189
3-Jun	-307	38	739	3629	3024	-211
4-Jun	-3835	1008	739	3715	1901	-5918
5-Jun	614	195	739	3888	1037	-1693
6-Jun	460	265	739	3715	259	-2522
7-Jun	1074	0	739	3715	173	-1729
8-Jun	614	0	739	3802	86	-2362
9-Jun	-460	0	739	3888	3197	-412
10-Jun	-5522	262	739	3974	4406	-4613
11-Jun	-1687	199	739	4061	950	-4258
12-Jun	1687	1733	739	4147	346	-3108
13-Jun	2454	943	739	4147	173	-1724
14-Jun	2148	0	739	4147	86	-1174
15-Jun	1074	74	739	4061	86	-2235
16-Jun	-614	0	739	3974	3802	-47
17-Jun	-3988	0	739	3888	1728	-5409
18-Jun	460	0	739	3888	173	-2516
19-Jun	614	0	739	3888	86	-2449
20-Jun	767	0	739	3888	86	-2295
21-Jun	614	0	739	3888	86	-2449
22-Jun	460	0	739	3888	86	-2602
23-Jun	614	2086	739	3974	2074	-2634
24-Jun	-460	0	739	3888	1210	-2399
25-Jun	460	1598	739	3888	259	-4028
26-Jun	1687	259	739	3974	86	-1721

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
27-Jun	1841	2419	739	4061	346	-3554
28-Jun	1534	2155	739	4320	4320	118
29-Jun	-1227	647	739	4234	1901	-3468
30-Jun	1687	488	739	4061	259	-1863
1-Jul	1381	0	745	3974	86	-1763
2-Jul	1074	675	745	3974	86	-2744
3-Jul	1687	1743	745	3974	173	-3112
4-Jul	1994	0	745	3974	173	-1063
5-Jul	767	0	745	3888	86	-2290
6-Jul	614	0	745	3802	86	-2357
7-Jul	460	471	745	3802	86	-2981
8-Jul	614	0	745	3802	86	-2357
9-Jul	307	0	745	3802	86	-2664
10-Jul	-460	0	745	3715	3110	-320
11-Jul	-6289	0	745	3715	3456	-5804
12-Jul	-1074	0	745	3715	432	-3612
13-Jul	307	0	745	3715	173	-2491
14-Jul	-1074	0	745	3715	3370	-675
15-Jul	-5676	0	745	3629	4234	-4326
16-Jul	-1841	0	745	3629	518	-4206
17-Jul	460	0	745	3629	86	-2337
18-Jul	153	0	745	3629	86	-2644
19-Jul	307	0	745	3629	86	-2491
20-Jul	153	0	745	3629	86	-2644
21-Jul	2915	6263	745	4234	173	-6665
22-Jul	6596	2915	745	3974	778	1230
23-Jul	1841	773	745	3974	3370	1208
24-Jul	-6289	123	745	3888	5962	-3594
25-Jul	-2301	0	745	3802	605	-4753
26-Jul	767	0	745	3715	259	-1944
27-Jul	767	0	745	3715	173	-2031
28-Jul	-614	0	745	3715	3197	-387
29-Jul	-3375	0	745	3715	2074	-4272
30-Jul	-460	49	745	3629	173	-3220

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
31-Jul	307	0	745	3629	86	-2491
1-Aug	460	0	520	3629	86	-2562
2-Aug	460	0	520	3629	86	-2562
3-Aug	460	480	520	3629	86	-3042
4-Aug	0	0	520	3629	1901	-1208
5-Aug	-2454	0	520	3629	1210	-4353
6-Aug	153	0	520	3629	259	-2696
7-Aug	460	0	520	3629	86	-2562
8-Aug	307	0	520	3542	86	-2629
9-Aug	153	0	520	3542	86	-2782
10-Aug	460	0	520	3542	86	-2476
11-Aug	-614	57	520	3542	2074	-1619
12-Aug	-2761	0	520	3542	1037	-4747
13-Aug	0	0	520	3542	173	-2849
14-Aug	153	0	520	3542	259	-2610
15-Aug	153	0	520	3542	1296	-1573
16-Aug	-2761	0	520	3456	2592	-3105
17-Aug	-1227	0	520	3542	691	-3558
18-Aug	153	0	520	3542	259	-2610
19-Aug	153	259	520	3542	86	-3042
20-Aug	460	0	520	3542	86	-2476
21-Aug	767	0	520	4061	86	-2687
22-Aug	614	0	520	3888	173	-2581
23-Aug	1381	1505	520	4061	259	-3406
24-Aug	1074	462	520	4147	346	-2669
25-Aug	0	0	520	3974	346	-3109
26-Aug	307	0	520	4061	346	-2888
27-Aug	460	0	520	4147	346	-2821
28-Aug	460	0	520	4147	432	-2735
29-Aug	767	75	520	4147	259	-2676
30-Aug	1687	3088	520	4493	432	-4941
31-Aug	3375	0	520	4579	864	180
1-Sep	920	0	213	4406	605	-2668
2-Sep	1074	0	213	4579	432	-2860

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
3-Sep	1534	609	213	4061	432	-2491
4-Sep	614	0	213	3974	346	-2802
5-Sep	307	0	213	4147	346	-3282
6-Sep	767	0	213	3974	432	-2562
7-Sep	-1074	0	213	3974	3283	-1552
8-Sep	-4142	2611	213	4234	3542	-7231
9-Sep	-920	166	213	4320	3283	-1910
10-Sep	-2148	0	213	4147	2246	-3835
11-Sep	-153	364	213	4147	864	-3587
12-Sep	614	0	213	4234	950	-2456
13-Sep	460	0	213	4234	518	-3042
14-Sep	767	135	213	4234	605	-2784
15-Sep	460	64	213	4234	605	-3020
16-Sep	307	0	213	4320	1382	-2418
17-Sep	-1687	0	213	4320	2333	-3461
18-Sep	-460	0	213	4320	605	-3962
19-Sep	767	130	213	4320	518	-2952
20-Sep	614	0	213	4234	605	-2802
21-Sep	460	58	213	4234	605	-3014
22-Sep	460	0	213	4234	605	-2955
23-Sep	614	0	213	4234	605	-2802
24-Sep	614	0	213	4234	605	-2802
25-Sep	614	0	213	4234	691	-2716
26-Sep	0	0	213	4234	2333	-1688
27-Sep	-4142	0	213	4147	3629	-4447
28-Sep	-2608	0	213	4147	2592	-3950
29-Sep	-1687	48	213	4147	2160	-3509
30-Sep	-920	0	213	4061	1814	-2954
1-Oct	-614	0	65	4061	1642	-2967
2-Oct	-460	0	65	4061	1555	-2900
3-Oct	-307	0	65	4061	1469	-2833
4-Oct	-153	167	65	3974	1469	-2761
5-Oct	153	0	65	3974	1469	-2287
6-Oct	-153	0	65	3888	1382	-2594

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.2 (Cont'd.)

Day	Lake Storage Change	Precipitation (NNLL Climate)	Evaporation (Morton)	Stream Inflow (CreekA)	Stream Outflow (Outlet)	Residual (GW)
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
7-Oct	0	0	65	3888	1382	-2440
8-Oct	-153	0	65	3802	1382	-2507
9-Oct	0	0	65	3802	1382	-2354
10-Oct	0	0	65	3715	1382	-2267
11-Oct	153	0	65	3715	1382	-2114
12-Oct	0	0	65	3715	1469	-2181
13-Oct	0	0	65	3715	1469	-2181
14-Oct	0	0	65	3629	1469	-2095
15-Oct	153	0	65	3715	1469	-2028
16-Oct	0	0	65	3629	2160	-1403
17-Oct	0	0	65	3629	2592	-971
18-Oct	0	0	65	3629	2333	-1231
19-Oct	0	0	65	3542	2074	-1403
20-Oct	0	0	65	3542	1987	-1490
21-Oct	0	0	65	3542	1901	-1576
22-Oct	0	0	65	3456	1814	-1576
23-Oct	0	0	65	3456	1728	-1663
24-Oct	0	0	65	3370	1728	-1576
25-Oct	0	0	65	3370	1642	-1663
26-Oct	0	58	65	3370	1642	-1721
27-Oct	0	0	65	3283	1642	-1576
28-Oct	0	0	65	3370	1555	-1749
29-Oct	0	0	65	3370	1555	-1749
30-Oct	0	0	65	3370	1555	-1749
31-Oct	0	0	65	3370	1555	-1749

Note: Red values indicate interpolated data points for the purpose of calculating the water balance.

Table A1.3 Daily Climate Data from NNLL Climate Station 2018 WY.

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
1-Nov	-0.3	-1.9	-4.2	84.5	98.9	-4.0	80	4.6	0.0	0.0
2-Nov	-3.1	-7.1	-9.2	75.1	100.3	-13.8	113	2.9	0.0	0.0
3-Nov	-8.7	-10.5	-12.0	71.1	99.9	-30.2	187	3.1	0.0	0.0
4-Nov	-7.3	-11.1	-14.2	77.7	99.0	-17.3	188	2.2	0.0	0.0
5-Nov	-5.3	-11.1	-16.2	68.2	98.9	-13.4	280	3.0	0.0	0.0
6-Nov	-4.7	-6.4	-9.0	66.6	99.0	-19.8	222	2.8	0.0	0.0
7-Nov	-4.3	-8.5	-14.0	68.0	99.8	-23.0	251	2.6	0.0	0.0
8-Nov	-6.0	-10.0	-14.3	70.2	99.8	-26.3	188	1.1	0.0	0.0
9-Nov	-7.3	-14.4	-20.7	73.7	98.8	-27.5	187	2.6	0.0	0.0
10-Nov	-3.5	-12.1	-21.0	74.1	98.3	-2.3	152	2.4	0.0	0.0
11-Nov	-5.2	-6.8	-8.5	74.7	98.9	-12.2	202	1.6	0.0	0.0
12-Nov	-4.7	-7.3	-10.1	75.3	99.4	-4.5	167	0.8	0.0	0.0
13-Nov	-6.7	-8.1	-9.9	77.8	98.5	-1.5	96	2.5	0.0	0.0
14-Nov	-6.1	-7.6	-9.8	78.7	99.6	-18.9	22	2.8	0.0	0.0
15-Nov	-9.3	-13.1	-19.6	77.2	99.4	-5.8	107	0.7	1.7	0.0
16-Nov	-10.6	-14.3	-20.5	78.0	97.5	-4.3	166	1.0	0.3	0.0
17-Nov	-7.4	-10.7	-14.5	69.4	97.9	-19.6	233	1.7	0.0	0.0
18-Nov	-9.8	-14.6	-20.7	79.0	98.7	-18.6	134	0.9	0.0	0.0
19-Nov	-14.7	-19.3	-23.9	82.7	97.8	2.1	17	1.6	9.1	0.0
20-Nov	-12.9	-17.1	-19.2	78.3	98.3	4.8	-	1.4	1.2	-
21-Nov	-12.3	-14.1	-20.9	80.4	99.5	8.3	211	1.0	0.0	0.0
22-Nov	-11.8	-16.1	-21.9	80.5	98.4	-0.4	153	0.4	5.3	0.0
23-Nov	-12.7	-17.7	-23.2	81.4	96.5	4.6	348	1.3	6.3	0.0
24-Nov	-4.4	-9.9	-15.1	78.5	97.8	12.6	184	0.5	0.0	0.0

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
25-Nov	-9.9	-16.4	-20.8	80.0	98.5	7.9	59	0.9	0.1	0.0
26-Nov	-8.6	-14.3	-22.6	82.1	98.5	4.0	-	0.8	6.3	-
27-Nov	-12.4	-15.3	-20.6	84.0	97.0	0.9	-	1.1	12.6	-
28-Nov	-11.8	-12.7	-19.7	82.3	97.5	-2.1	181	0.9	19.8	0.0
29-Nov	-6.6	-15.9	-24.5	83.5	97.7	2.1	-	1.2	0.0	-
30-Nov	-7.7	-10.3	-14.5	84.9	97.4	-21.5	177	2.1	8.5	0.0
1-Dec	2.0	-3.8	-8.7	84.9	97.5	-19.2	209	1.6	2.8	0.0
2-Dec	-2.8	-8.0	-14.7	83.3	97.9	9.9	290	0.4	0.0	0.0
3-Dec	-10.6	-14.0	-22.3	79.0	98.4	15.5	30	0.8	0.9	0.0
4-Dec	-11.8	-16.5	-24.3	71.7	99.1	33.1	-	0.9	4.0	-
5-Dec	-13.2	-22.3	-30.9	84.1	99.1	3.8	-	1.0	0.0	-
6-Dec	-8.5	-11.5	-16.5	84.9	99.8	14.1	175	0.7	0.0	0.0
7-Dec	-2.9	-11.1	-19.2	84.3	99.1	-7.4	201	1.1	0.0	0.1
8-Dec	2.7	-7.3	-14.7	89.3	98.8	-19.8	187	0.7	0.0	0.0
9-Dec	-2.5	-7.7	-13.4	72.1	98.2	-22.4	203	2.3	0.2	0.6
10-Dec	7.8	0.7	-7.3	93.0	98.7	-0.6	121	1.1	11.7	0.0
11-Dec	0.1	-4.4	-8.2	91.0	99.1	-7.6	0	0.5	0.0	0.0
12-Dec	0.1	-6.6	-14.6	88.2	98.2	-30.5	131	0.9	0.0	0.0
13-Dec	3.5	-1.3	-5.9	88.2	99.1	-8.5	155	1.2	0.0	0.1
14-Dec	1.5	-2.2	-7.1	89.5	98.8	-5.5	191	0.7	0.0	0.0
15-Dec	-2.1	-6.4	-13.6	83.9	97.0	-11.5	211	1.5	6.3	0.3
16-Dec	4.7	-0.2	-4.0	82.7	97.9	-6.9	97	1.7	0.6	0.0
17-Dec	-1.2	-8.9	-12.7	80.2	96.4	-8.7	239	2.4	5.5	0.2
18-Dec	3.2	-2.5	-11.3	74.4	97.6	-11.7	154	2.6	0.0	0.0

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
19-Dec	-0.9	-10.5	-17.7	67.7	99.4	10.2	-	0.6	0.0	-
20-Dec	-17.3	-25.0	-30.1	69.4	98.8	9.1	165	0.7	0.0	0.0
21-Dec	-16.1	-24.0	-28.9	79.0	98.8	-2.8	-	0.5	0.5	-
22-Dec	-6.4	-13.1	-22.3	75.3	99.2	-3.2	-	1.5	1.3	-
23-Dec	-5.6	-11.6	-23.6	66.0	99.7	7.7	-	0.4	0.2	-
24-Dec	-20.4	-27.4	-34.0	61.4	100.6	0.4	-	0.9	0.1	-
25-Dec	-20.4	-29.6	-36.0	55.8	101.0	-0.3	-	0.5	0.0	-
26-Dec	-28.7	-35.9	-40.6	57.2	100.4	-0.9	-	0.5	0.0	-
27-Dec	-29.3	-34.7	-39.3	62.5	99.9	-2.4	-	0.4	0.0	-
28-Dec	-24.9	-29.4	-33.7	59.3	100.6	-1.0	-	0.3	0.0	-
29-Dec	-26.4	-32.2	-40.1	55.1	101.4	-0.3	-	0.5	0.0	-
30-Dec	-27.9	-35.6	-42.3	61.9	101.1	-4.0	-	0.4	0.0	-
31-Dec	-24.4	-30.1	-34.9	60.8	100.9	1.5	0	1.7	0.0	-
1-Jan	-23.5	-27.6	-34.1	64.4	99.2	6.1	195	1.6	0.0	0.0
2-Jan	-17.2	-22.5	-27.1	69.2	99.7	3.4	93	1.2	0.0	0.0
3-Jan	-17.2	-22.1	-30.2	77.6	99.1	-3.2	-	0.6	0.0	-
4-Jan	-12.2	-17.7	-24.6	81.4	99.1	0.8	-	1.7	0.0	-
5-Jan	-9.9	-11.6	-13.3	80.9	98.5	18.8	196	2.4	0.0	0.0
6-Jan	-6.9	-8.8	-10.1	78.1	97.3	4.1	271	1.6	0.6	0.0
7-Jan	1.5	-7.2	-15.2	73.8	97.7	13.8	71	1.7	0.0	0.0
8-Jan	0.8	-8.4	-13.7	71.2	98.5	0.7	-	2.7	0.6	-
9-Jan	-10.5	-16.3	-21.5	61.7	99.3	2.3	-	2.5	2.1	-
10-Jan	-21.4	-24.6	-26.4	63.1	99.8	1.0	118	0.5	0.4	0.0
11-Jan	-23.0	-28.0	-35.4	58.3	100.1	5.0	-	0.8	0.0	-

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m^2)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
12-Jan	-24.0	-33.0	-38.2	57.9	100.2	6.1	-	0.9	0.0	-
13-Jan	-24.7	-33.3	-41.0	66.1	99.4	-1.6	-	0.8	0.1	-
14-Jan	-20.0	-24.9	-30.5	60.9	101.1	8.3	-	0.6	0.0	-
15-Jan	-21.7	-30.2	-36.3	64.7	100.1	19.6	166	3.0	0.0	0.0
16-Jan	-10.3	-16.5	-23.7	72.3	98.3	20.8	0	1.8	0.0	-
17-Jan	-8.2	-12.8	-19.0	80.5	97.6	8.9	0	0.5	0.0	-
18-Jan	-1.8	-12.7	-20.7	88.7	96.5	12.5	142	0.5	0.1	0.0
19-Jan	0.0	-5.7	-13.7	88.1	96.9	-0.8	-	1.3	1.0	-
20-Jan	-2.7	-6.3	-8.7	86.6	98.2	-3.2	-	0.5	1.8	-
21-Jan	-8.5	-9.1	-11.5	80.0	99.0	1.7	-	0.7	0.0	-
22-Jan	-11.1	-16.7	-22.2	84.6	98.5	-2.2	125	0.4	1.0	0.0
23-Jan	-10.0	-12.0	-16.5	84.7	99.0	-5.3	170	0.6	5.1	0.0
24-Jan	-9.0	-12.0	-13.3	85.8	98.6	-6.0	194	0.7	3.2	0.0
25-Jan	-8.5	-10.7	-14.1	78.5	98.4	5.0	357	1.9	0.4	0.0
26-Jan	-12.3	-14.0	-16.2	69.7	99.5	5.5	-	2.8	0.3	-
27-Jan	-16.0	-18.4	-23.9	66.4	100.7	10.3	-	0.7	0.0	-
28-Jan	-23.1	-26.2	-30.0	61.7	101.2	17.4	-	0.4	0.0	-
29-Jan	-21.1	-29.2	-34.0	70.3	99.4	7.4	256	0.5	2.6	0.0
30-Jan	-14.7	-22.3	-33.9	64.3	98.0	4.9	-	1.7	2.6	-
31-Jan	-14.6	-17.2	-22.2	66.7	100.2	8.0	-	0.7	0.0	-
1-Feb	-20.3	-24.4	-29.7	63.2	100.4	9.8	330	0.3	0.4	0.0
2-Feb	-24.1	-27.9	-35.0	57.2	100.2	14.2	-	0.3	0.0	-
3-Feb	-25.9	-33.9	-40.1	52.9	100.0	30.5	-	1.1	0.0	-
4-Feb	-16.4	-28.5	-40.2	59.5	98.8	3.3	345	2.6	0.0	0.0

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
5-Feb	-12.1	-15.7	-20.3	72.3	99.4	-14.0	198	1.0	0.0	0.0
6-Feb	-13.7	-20.3	-28.2	68.8	99.6	-27.1	171	1.3	0.0	0.0
7-Feb	-14.7	-21.2	-30.4	67.7	99.9	-6.4	224	1.8	0.0	0.0
8-Feb	-15.2	-20.0	-29.2	69.0	100.4	-23.1	189	1.3	0.0	0.0
9-Feb	-10.0	-16.3	-19.7	63.8	99.4	-16.3	216	1.8	0.0	0.0
10-Feb	-8.2	-13.2	-20.7	66.6	98.7	-22.1	161	3.9	0.0	0.0
11-Feb	-8.9	-13.8	-23.4	67.7	100.3	-29.7	166	1.4	0.0	0.0
12-Feb	-17.7	-24.9	-34.4	62.9	98.0	-16.4	188	4.3	0.0	0.0
13-Feb	-5.8	-14.9	-22.7	73.8	96.7	1.2	132	3.2	0.0	0.0
14-Feb	-0.5	-4.5	-14.6	64.9	99.3	-23.8	130	3.5	0.0	0.0
15-Feb	-11.6	-24.4	-32.3	61.7	98.7	-22.8	188	1.9	0.0	0.0
16-Feb	-7.0	-18.0	-26.5	66.2	98.3	-21.5	224	1.2	0.0	0.0
17-Feb	-8.7	-20.3	-31.6	62.8	98.6	-7.8	203	2.7	0.0	0.0
18-Feb	-11.5	-16.2	-22.9	64.0	99.2	-13.5	127	1.6	0.0	0.0
19-Feb	-17.5	-20.8	-27.0	71.6	98.5	-13.6	162	4.0	0.0	0.0
20-Feb	-8.8	-17.3	-23.2	67.6	99.7	-26.5	153	0.9	0.0	0.0
21-Feb	-21.5	-27.9	-35.2	63.7	98.5	-14.8	209	2.3	0.6	0.0
22-Feb	-8.0	-17.7	-33.0	69.2	98.8	-5.9	157	1.3	0.0	0.0
23-Feb	-4.5	-10.3	-17.8	68.0	97.3	-1.7	170	2.4	0.3	0.0
24-Feb	-0.3	-8.2	-18.5	76.6	97.5	-11.4	108	2.2	0.0	0.0
25-Feb	-4.5	-10.5	-22.0	77.2	96.9	4.6	178	1.1	0.0	0.0
26-Feb	-5.4	-12.4	-21.8	72.7	97.5	-18.9	191	2.0	0.0	0.0
27-Feb	-1.7	-10.2	-22.2	73.5	96.6	-4.3	170	2.4	0.0	0.5
28-Feb	3.4	-2.7	-9.4	73.2	98.2	-13.2	90	1.2	0.0	0.0

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
1-Mar	-4.6	-11.6	-22.7	70.0	100.1	-14.4	111	1.7	0.0	0.0
2-Mar	-8.9	-18.2	-27.8	70.9	100.6	-3.8	105	1.1	0.0	0.0
3-Mar	-12.1	-18.8	-26.3	71.5	100.2	10.6	182	0.5	0.0	0.0
4-Mar	-2.2	-12.1	-22.1	79.3	100.0	-1.7	207	0.4	0.0	0.0
5-Mar	-3.4	-9.5	-14.5	87.3	99.6	2.8	136	1.2	2.5	0.0
6-Mar	-5.7	-9.1	-14.5	77.8	99.6	-24.5	223	1.0	0.2	0.0
7-Mar	-4.0	-10.9	-17.5	67.9	99.3	-8.3	185	0.8	0.0	0.0
8-Mar	-3.0	-12.3	-21.3	63.3	98.4	-9.7	194	1.4	0.0	0.2
9-Mar	0.8	-12.5	-25.4	69.8	97.5	1.5	225	1.4	0.0	0.3
10-Mar	1.2	-7.3	-16.3	64.7	98.5	-0.6	182	1.4	0.0	0.8
11-Mar	9.0	-5.9	-18.6	66.1	99.5	8.5	197	0.7	0.0	1.0
12-Mar	9.5	-2.9	-14.8	60.7	99.2	14.9	197	2.2	0.0	1.8
13-Mar	11.2	0.9	-10.9	58.3	98.9	19.1	177	1.2	0.0	1.5
14-Mar	9.9	2.6	-4.7	68.6	98.6	13.3	197	0.8	0.0	1.4
15-Mar	10.1	-0.7	-10.8	69.5	98.2	14.1	186	1.2	0.0	1.3
16-Mar	6.8	-1.3	-10.1	65.9	98.3	20.8	173	1.1	0.0	1.1
17-Mar	9.0	-0.9	-9.8	65.3	99.1	18.5	15	3.7	0.0	0.0
18-Mar	0.1	-3.6	-7.9	62.1	99.5	25.7	190	0.8	0.0	0.5
19-Mar	2.6	-5.8	-13.5	65.5	98.7	29.2	193	2.8	0.0	1.1
20-Mar	5.1	-2.4	-12.0	75.0	98.2	26.5	48	2.4	0.6	0.7
21-Mar	2.5	0.1	-1.6	72.6	99.5	33.4	15	4.0	0.0	0.0
22-Mar	-1.2	-9.6	-16.2	71.6	100.2	29.8	25	3.0	0.0	0.0
23-Mar	-8.2	-11.7	-16.2	84.1	98.4	-23.3	203	1.2	5.8	0.0
24-Mar	0.5	-4.9	-13.0	67.3	98.0	-22.0	244	2.7	0.4	0.0

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
25-Mar	-0.4	-6.6	-19.9	67.6	98.7	19.1	152	1.2	0.0	0.0
26-Mar	-9.5	-16.1	-22.4	72.3	98.5	18.1	28	3.6	2.7	0.0
27-Mar	-10.4	-15.3	-25.6	66.5	98.6	5.8	202	0.8	0.0	0.0
28-Mar	-6.5	-18.0	-27.7	59.5	99.2	17.2	74	3.1	0.0	0.0
29-Mar	-13.4	-18.8	-26.8	54.7	100.4	25.0	188	1.0	0.0	0.0
30-Mar	-14.8	-23.3	-32.7	54.4	100.3	33.2	242	1.6	0.0	0.0
31-Mar	-9.6	-19.1	-32.8	38.2	99.7	36.3	258	3.7	0.0	0.0
1-Apr	-0.4	-7.4	-19.7	58.6	99.1	55.1	81	1.7	0.0	0.0
2-Apr	-5.4	-11.3	-20.8	65.8	99.2	44.7	133	1.2	0.0	0.0
3-Apr	-6.2	-11.2	-16.8	62.4	99.6	41.4	110	1.0	0.0	0.0
4-Apr	-9.5	-16.3	-25.2	65.3	99.5	24.1	171	2.8	0.0	0.0
5-Apr	-10.7	-16.5	-26.8	56.8	100.6	50.9	60	3.0	0.0	0.0
6-Apr	-10.2	-15.6	-22.2	54.2	100.5	60.6	153	1.0	0.0	0.0
7-Apr	-4.4	-14.3	-25.4	55.5	99.2	53.5	183	0.9	0.0	0.5
8-Apr	2.4	-10.0	-22.9	56.4	98.8	58.5	201	1.8	0.0	1.6
9-Apr	3.7	-6.5	-18.5	60.3	98.9	74.1	124	1.4	0.0	2.1
10-Apr	4.1	-4.3	-14.6	52.9	99.2	69.8	48	3.0	0.0	0.0
11-Apr	-4.9	-8.4	-15.9	59.3	98.8	69.9	133	1.7	0.0	0.0
12-Apr	-4.7	-11.7	-21.2	56.5	98.7	76.0	219	0.7	0.0	0.9
13-Apr	3.9	-7.7	-20.3	65.9	98.9	56.3	200	2.4	0.0	2.0
14-Apr	5.5	-1.8	-13.6	68.2	98.4	57.2	173	2.4	0.0	2.0
15-Apr	9.4	3.8	-2.8	71.6	98.7	118.1	113	3.2	0.0	2.8
16-Apr	10.4	2.1	-3.3	82.6	99.1	52.4	12	5.0	1.2	0.0
17-Apr	0.6	-1.8	-4.0	88.4	97.9	19.2	142	1.5	3.7	0.5

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m^2)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
18-Apr	3.2	1.4	-0.1	63.1	98.6	92.5	218	3.0	0.0	2.8
19-Apr	10.4	3.3	-2.2	50.4	98.7	118.8	199	3.8	0.0	6.0
20-Apr	16.1	7.1	-3.8	40.8	98.3	107.4	201	3.7	0.0	6.0
21-Apr	17.1	10.3	3.2	51.8	98.2	71.0	130	1.3	0.0	3.0
22-Apr	15.0	8.3	-1.2	73.2	98.6	59.9	120	3.3	0.5	2.2
23-Apr	9.5	5.0	-1.0	65.0	99.6	123.4	169	1.2	0.0	3.1
24-Apr	14.2	4.6	-3.3	41.7	98.5	100.2	225	3.8	0.0	6.7
25-Apr	18.4	9.7	-0.9	48.6	98.6	110.8	202	1.5	0.0	4.4
26-Apr	18.8	8.5	-2.6	38.4	98.9	129.8	132	2.8	0.0	5.6
27-Apr	14.8	9.8	-0.8	44.2	98.3	115.2	195	2.5	0.0	6.6
28-Apr	24.6	11.4	-3.0	52.6	97.3	104.8	44	3.6	0.0	5.3
29-Apr	16.9	9.4	0.8	57.5	98.5	138.9	118	3.6	0.3	4.1
30-Apr	11.4	5.4	-2.5	47.5	98.1	101.6	165	2.6	0.0	4.7
1-May	16.9	7.8	-3.6	56.7	98.1	140.1	77	3.0	0.0	4.1
2-May	12.3	7.8	-0.9	57.5	97.5	72.4	207	2.4	0.0	4.1
3-May	18.4	7.2	-4.2	61.1	98.0	105.9	121	2.5	0.0	4.2
4-May	16.2	8.4	-0.1	69.0	98.6	61.8	127	1.3	0.0	1.9
5-May	13.4	6.8	2.3	54.6	98.5	84.1	226	1.5	0.0	4.3
6-May	23.5	12.7	4.0	37.9	98.3	128.7	242	3.2	0.0	8.7
7-May	25.5	17.3	6.3	35.8	99.3	118.8	97	3.1	0.0	5.8
8-May	18.1	12.3	5.6	46.4	98.6	136.6	274	5.3	0.0	7.4
9-May	21.7	11.5	4.1	38.8	99.5	134.9	185	1.6	0.0	4.7
10-May	16.4	8.6	-1.6	38.0	98.7	126.5	205	2.6	0.0	6.4
11-May	20.2	11.1	-0.6	39.2	98.4	124.6	168	3.2	0.0	7.3

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
12-May	23.2	15.5	6.4	37.1	97.9	94.4	267	4.3	0.0	9.1
13-May	24.7	17.8	10.4	55.1	98.7	56.3	211	2.6	0.3	3.9
14-May	15.7	11.0	5.1	48.2	98.6	64.0	85	1.3	0.0	3.1
15-May	17.0	9.4	0.5	52.5	98.0	105.1	138	2.7	0.0	5.2
16-May	21.7	13.6	6.5	52.2	99.2	140.1	60	3.5	0.7	5.3
17-May	16.9	10.6	4.3	40.2	99.7	90.8	133	1.9	0.3	4.6
18-May	19.8	11.5	3.2	38.5	99.5	127.2	187	1.4	0.0	5.6
19-May	23.9	13.9	0.4	33.6	98.9	139.3	201	3.0	0.0	8.8
20-May	26.5	18.4	7.0	37.7	98.1	142.7	193	2.4	0.3	8.4
21-May	28.6	18.8	5.8	42.9	97.9	123.6	193	1.5	0.0	6.5
22-May	30.5	20.5	8.6	41.2	98.1	142.2	198	3.0	0.0	10.1
23-May	31.0	21.8	7.6	37.1	98.0	144.9	192	1.7	0.0	8.1
24-May	35.0	24.5	12.0	45.8	97.6	117.3	207	1.6	0.0	6.3
25-May	33.5	23.2	12.7	72.7	97.5	61.0	181	1.0	1.5	2.8
26-May	26.5	19.6	13.3	59.1	97.5	93.7	208	3.4	2.7	6.3
27-May	22.6	16.2	8.9	46.8	98.2	135.3	188	2.4	0.0	7.1
28-May	25.4	17.2	8.9	42.4	97.9	99.7	224	2.9	0.0	7.2
29-May	25.3	18.5	11.4	52.4	98.3	57.4	204	3.3	0.0	4.3
30-May	16.2	12.6	5.1	63.0	98.6	71.7	179	1.4	0.0	3.0
31-May	17.1	10.7	2.8	42.5	98.8	151.4	103	1.8	0.0	5.9
1-Jun	20.9	13.5	5.3	56.0	98.9	65.1	162	1.7	0.2	3.9
2-Jun	18.8	12.2	3.5	76.1	98.8	69.4	216	1.2	0.0	2.3
3-Jun	17.6	12.1	8.3	70.2	98.9	111.9	13	3.3	0.3	3.9
4-Jun	14.2	10.8	4.9	80.6	98.5	6.5	25	2.4	6.6	1.2

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m^2)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
5-Jun	9.6	6.4	2.7	85.1	98.1	55.0	181	2.3	1.3	1.7
6-Jun	13.4	8.0	2.3	70.2	98.3	136.0	190	2.1	1.7	4.4
7-Jun	19.7	10.3	0.3	56.5	98.3	173.2	171	1.4	0.0	6.0
8-Jun	27.0	17.4	4.7	52.8	98.1	102.1	193	2.0	0.0	6.4
9-Jun	29.3	19.7	9.0	59.3	97.5	152.4	164	1.9	0.0	7.2
10-Jun	31.9	21.8	9.7	82.8	96.8	18.8	33	3.6	1.7	1.9
11-Jun	23.1	16.8	14.2	78.9	96.1	39.0	88	2.0	1.3	2.0
12-Jun	15.1	13.2	11.6	90.3	96.8	15.5	196	2.8	11.3	1.0
13-Jun	13.4	11.1	9.5	84.2	97.5	29.3	206	1.2	6.2	1.1
14-Jun	13.0	9.4	7.4	71.7	97.9	76.7	194	1.8	0.0	2.7
15-Jun	16.8	11.3	6.6	62.5	98.2	180.0	193	0.9	0.5	5.1
16-Jun	22.5	14.2	3.3	54.2	98.7	172.6	134	1.1	0.0	6.0
17-Jun	25.3	18.0	7.2	49.6	98.4	138.1	206	2.7	0.0	8.5
18-Jun	30.1	20.6	7.1	45.6	98.6	155.4	168	2.3	0.0	8.3
19-Jun	33.6	23.8	14.6	48.8	98.5	117.6	206	2.4	0.0	8.1
20-Jun	32.9	23.8	11.3	45.9	98.2	173.0	154	2.1	0.0	9.3
21-Jun	35.9	26.3	15.3	56.4	98.2	129.8	188	1.7	0.0	6.6
22-Jun	33.8	23.4	15.3	71.4	97.9	103.4	156	1.5	0.0	4.1
23-Jun	29.5	20.7	14.0	79.6	98.0	102.8	173	1.6	13.6	4.1
24-Jun	30.5	20.6	16.0	62.7	98.0	178.8	177	2.8	0.0	8.2
25-Jun	32.7	23.6	15.7	62.2	97.5	143.8	131	2.0	10.4	6.9
26-Jun	33.2	22.5	12.1	77.1	97.3	66.4	190	1.9	1.7	2.8
27-Jun	21.4	16.4	12.0	90.7	96.9	15.8	197	3.2	15.8	1.1
28-Jun	17.1	13.2	11.1	87.6	97.4	78.4	230	1.6	14.1	2.1

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
29-Jun	19.6	14.4	12.0	83.5	97.9	78.8	192	1.4	4.2	2.5
30-Jun	19.8	15.2	11.2	72.7	97.7	148.5	201	1.7	3.2	4.8
1-Jul	24.8	16.8	8.5	68.4	97.5	154.6	172	1.7	0.0	5.3
2-Jul	24.8	17.4	10.6	86.2	98.0	66.4	53	2.8	4.4	2.4
3-Jul	20.4	15.7	11.6	89.2	98.9	85.6	23	2.7	11.4	2.3
4-Jul	19.8	15.8	12.1	63.6	99.3	170.4	159	1.9	0.0	6.2
5-Jul	22.3	16.7	9.4	55.9	99.2	164.2	203	3.1	0.0	8.7
6-Jul	29.4	20.0	7.1	58.8	98.0	111.0	210	2.6	0.0	6.8
7-Jul	29.8	22.3	13.1	69.9	97.7	34.2	260	3.1	3.1	2.8
8-Jul	21.1	15.2	10.5	57.8	98.5	92.1	224	2.6	0.0	5.2
9-Jul	24.0	16.6	7.8	54.2	98.5	154.6	207	2.7	0.0	7.9
10-Jul	28.8	21.0	11.7	54.4	98.2	133.8	203	3.7	0.0	8.3
11-Jul	29.7	22.6	14.9	47.8	98.0	160.5	242	2.6	0.0	9.2
12-Jul	30.1	23.4	13.2	63.0	98.3	47.0	214	0.7	0.0	2.5
13-Jul	27.4	19.2	12.1	70.3	98.4	83.3	193	2.2	0.0	4.2
14-Jul	26.4	17.5	9.6	66.7	98.4	62.5	269	3.1	0.0	3.3
15-Jul	18.5	14.2	11.7	62.3	98.8	147.6	239	2.1	0.0	4.7
16-Jul	22.2	15.3	9.1	64.9	98.2	98.8	183	2.0	0.0	4.9
17-Jul	28.4	19.4	11.3	53.6	98.3	152.7	214	2.3	0.0	7.8
18-Jul	27.7	21.5	12.8	58.7	98.4	94.1	186	1.0	0.0	4.1
19-Jul	26.6	19.1	9.4	67.0	98.7	146.9	17	4.1	0.0	6.0
20-Jul	22.5	19.0	14.5	62.4	98.8	83.0	43	2.4	0.0	4.6
21-Jul	25.7	19.5	12.2	86.5	98.4	64.5	91	2.1	40.8	2.2
22-Jul	21.5	16.9	13.3	86.4	98.8	16.0	224	5.0	19.0	2.2

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
23-Jul	18.1	14.6	12.2	83.6	99.6	-18.8	277	3.3	5.0	1.3
24-Jul	14.2	13.2	12.2	85.2	99.6	65.5	49	2.2	0.8	2.1
25-Jul	19.6	15.0	11.4	74.0	99.6	108.8	189	1.1	0.0	3.8
26-Jul	23.4	17.0	7.4	63.8	99.3	147.7	199	1.6	0.0	5.8
27-Jul	29.0	20.5	11.3	58.4	98.9	137.3	202	2.2	0.0	6.6
28-Jul	30.3	21.9	12.7	56.7	98.5	126.9	197	2.6	0.0	7.1
29-Jul	32.4	23.7	16.0	68.7	98.9	130.9	19	3.2	0.0	5.5
30-Jul	24.6	20.3	14.3	75.6	99.0	83.5	71	2.5	0.3	4.0
31-Jul	23.1	17.3	12.7	70.3	99.2	131.4	186	1.4	0.0	4.6
1-Aug	24.8	16.6	7.6	72.2	98.1	111.3	190	1.3	0.0	4.4
2-Aug	27.7	19.8	10.4	65.7	97.7	141.2	217	1.4	0.0	5.8
3-Aug	30.3	21.0	11.1	72.4	97.3	103.5	186	2.8	3.1	4.7
4-Aug	29.7	21.0	14.7	67.8	98.2	97.9	146	4.1	0.0	4.8
5-Aug	20.4	17.1	10.3	65.9	98.4	117.4	201	2.6	0.0	6.0
6-Aug	28.2	18.5	7.1	73.5	97.7	61.7	138	1.1	0.0	2.7
7-Aug	25.4	20.5	14.1	64.2	97.6	103.9	172	1.9	0.0	5.1
8-Aug	27.2	21.3	14.9	53.5	97.9	110.0	196	2.4	0.0	7.1
9-Aug	30.4	23.4	14.8	61.5	98.0	76.0	198	1.8	0.0	4.6
10-Aug	28.6	22.5	15.0	67.8	97.8	29.2	205	2.1	0.0	3.2
11-Aug	27.3	21.8	15.5	56.7	98.9	120.1	82	2.7	0.4	5.3
12-Aug	20.4	16.4	10.7	62.2	99.3	61.1	197	0.9	0.0	2.7
13-Aug	20.2	12.9	5.8	62.1	98.5	84.9	191	3.8	0.0	6.3
14-Aug	24.7	15.7	4.7	53.2	97.3	92.3	226	3.1	0.0	5.9
15-Aug	28.8	21.5	16.2	62.0	98.1	86.5	97	3.0	0.0	4.6

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
16-Aug	21.1	17.6	7.6	67.2	98.7	90.3	188	2.1	0.0	4.8
17-Aug	27.4	16.1	4.6	56.6	98.1	84.4	185	1.8	0.0	4.9
18-Aug	28.5	20.5	13.4	48.2	98.7	67.6	289	3.1	0.0	5.3
19-Aug	20.6	17.4	11.1	69.6	99.3	94.9	98	2.1	1.7	4.2
20-Aug	21.1	14.6	9.7	59.9	99.3	71.4	220	2.1	0.0	4.9
21-Aug	25.6	16.8	8.4	48.6	98.5	86.2	207	3.1	0.0	6.6
22-Aug	28.1	20.3	10.7	65.0	97.8	15.3	96	3.7	0.0	3.0
23-Aug	20.1	15.8	8.1	81.1	98.6	21.6	35	1.7	9.8	1.1
24-Aug	11.0	8.6	6.6	89.8	98.4	7.3	169	2.2	3.0	0.7
25-Aug	9.0	7.7	5.8	81.5	98.4	49.4	182	2.0	0.0	1.5
26-Aug	10.8	7.9	5.0	76.5	98.4	29.7	55	1.9	0.0	1.9
27-Aug	14.0	8.8	2.1	66.9	98.9	51.8	166	1.3	0.0	2.6
28-Aug	14.9	9.3	0.1	76.3	98.0	14.8	183	1.2	0.0	1.1
29-Aug	16.1	10.9	5.7	92.6	97.6	5.2	33	2.0	0.5	0.6
30-Aug	13.0	9.8	4.8	94.9	97.3	-12.3	234	2.9	20.1	0.3
31-Aug	12.4	11.2	9.3	78.5	97.4	75.6	182	2.2	0.0	2.9
1-Sep	19.0	12.3	8.3	77.3	97.5	22.8	242	3.0	0.0	2.1
2-Sep	14.3	10.5	6.2	59.1	98.1	82.1	212	1.9	0.0	3.5
3-Sep	19.9	11.1	5.0	84.5	98.6	-9.8	252	3.5	4.0	1.0
4-Sep	9.9	7.5	4.0	58.4	99.3	66.0	211	2.7	0.0	3.7
5-Sep	15.0	7.3	-1.4	62.4	99.5	60.1	94	3.0	0.0	3.2
6-Sep	13.4	8.5	0.5	76.2	100.1	30.6	188	0.8	0.0	1.4
7-Sep	10.5	4.7	-2.8	80.7	99.0	30.9	210	0.4	0.0	1.2
8-Sep	16.7	8.3	-0.3	95.2	98.3	0.4	121	2.3	17.0	0.4

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
9-Sep	12.2	10.0	6.9	87.7	98.8	-2.8	236	4.8	1.1	0.9
10-Sep	9.7	5.9	0.3	83.7	98.4	45.4	191	1.8	0.0	1.4
11-Sep	11.9	4.8	-0.6	86.6	98.5	3.0	99	3.0	2.4	1.0
12-Sep	7.4	4.0	0.1	76.6	99.3	26.5	130	3.0	0.0	1.3
13-Sep	4.2	1.6	-0.6	61.8	99.3	30.8	190	1.1	0.0	1.4
14-Sep	7.9	2.6	-1.7	62.9	99.6	43.5	195	2.6	0.9	2.5
15-Sep	9.7	2.6	-3.8	65.0	99.8	52.2	176	0.7	0.4	2.0
16-Sep	10.8	2.5	-4.4	66.5	99.7	45.6	100	1.0	0.0	2.1
17-Sep	10.4	2.0	-6.1	66.7	99.2	45.4	192	2.1	0.0	2.4
18-Sep	11.8	3.6	-5.6	64.2	99.1	46.0	93	2.1	0.0	2.1
19-Sep	9.0	4.9	0.0	63.1	99.2	53.1	129	1.1	0.9	1.9
20-Sep	10.6	4.3	-0.3	54.8	99.7	33.2	122	2.6	0.0	1.9
21-Sep	5.3	1.2	-5.8	63.2	99.7	24.6	177	0.6	0.4	1.4
22-Sep	8.5	-0.7	-8.6	59.7	99.4	23.0	176	1.7	0.0	2.3
23-Sep	11.0	0.7	-8.7	69.2	98.5	2.7	185	2.5	0.0	1.1
24-Sep	6.1	2.1	-3.4	63.8	98.3	23.7	219	1.9	0.0	2.5
25-Sep	12.6	5.7	-0.8	64.5	98.5	13.9	212	2.4	0.0	2.5
26-Sep	15.0	6.4	-4.0	73.2	98.7	11.7	279	3.9	0.0	1.6
27-Sep	10.3	6.9	1.4	55.1	99.8	7.7	188	2.9	0.0	1.6
28-Sep	3.5	0.6	-2.5	56.5	99.4	34.6	252	3.1	0.0	2.1
29-Sep	7.0	2.8	-1.9	72.5	99.8	27.4	247	3.7	0.3	0.9
30-Sep	2.1	0.1	-2.0	61.7	99.6	14.5	212	2.0	0.0	1.5
1-Oct	6.5	1.1	-4.9	66.0	99.0	12.1	212	2.1	0.0	1.0
2-Oct	6.0	0.3	-4.6	64.5	98.6	0.4	227	3.2	0.0	1.5

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m²)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
3-Oct	5.8	-0.1	-6.0	68.3	98.9	7.2	189	2.5	0.0	0.1
4-Oct	0.6	-2.1	-7.7	79.2	99.1	10.8	116	1.2	1.1	0.5
5-Oct	2.2	-3.8	-11.4	75.6	99.0	13.9	92	3.7	0.0	0.0
6-Oct	-2.0	-3.9	-6.7	74.8	99.3	10.9	128	1.1	0.0	0.1
7-Oct	0.4	-3.5	-8.1	73.7	100.2	19.2	21	2.4	0.0	0.1
8-Oct	0.5	-2.4	-6.0	69.6	100.4	-2.0	191	0.7	0.0	0.3
9-Oct	1.9	-5.5	-12.5	66.9	100.5	0.7	189	0.9	0.0	0.9
10-Oct	4.6	-5.0	-12.3	64.2	99.8	9.4	192	1.2	0.0	1.1
11-Oct	6.7	-2.5	-10.7	65.0	98.5	5.2	187	2.1	0.0	1.0
12-Oct	3.9	1.8	-0.5	65.9	98.1	8.9	223	4.8	0.0	0.6
13-Oct	2.4	0.0	-2.2	60.7	99.6	4.4	195	2.7	0.0	0.3
14-Oct	2.8	-2.0	-7.8	72.5	98.5	-0.1	178	2.8	0.0	1.1
15-Oct	10.2	1.0	-7.8	62.1	98.6	-9.0	158	2.4	0.0	1.6
16-Oct	10.3	5.4	-4.2	83.3	99.3	4.7	203	1.2	0.0	0.6
17-Oct	4.5	-0.2	-5.8	59.0	98.0	9.5	200	2.4	0.0	2.3
18-Oct	18.4	7.4	-1.6	57.9	98.2	9.1	222	3.3	0.0	3.1
19-Oct	13.8	8.3	0.5	65.2	99.8	1.4	119	2.4	0.0	0.5
20-Oct	5.3	0.5	-3.1	48.5	98.1	4.3	216	3.4	0.0	2.6
21-Oct	16.4	6.7	-1.6	53.6	98.7	-13.7	130	2.7	0.0	2.0
22-Oct	10.2	4.7	-5.8	71.9	99.2	-12.4	203	1.9	0.0	1.1
23-Oct	10.2	0.8	-6.9	58.7	98.4	-9.2	195	2.3	0.0	1.8
24-Oct	13.4	4.1	-2.7	73.6	98.1	-7.1	205	0.5	0.0	0.7
25-Oct	12.8	1.3	-5.2	77.4	98.0	-7.7	195	1.2	0.0	0.9
26-Oct	9.1	1.1	-5.1	73.1	97.6	-3.7	202	1.7	0.4	1.1

Table A1.3 (Cont'd.)

Date	Daily Maximum Air Temperature (°C)	Daily Mean Air Temperature (°C)	Daily Minimum Air Temperature (°C)	Daily Mean Relative Humidity (%)	Daily Mean Atmospheric Pressure (kPa)	Daily Mean Net Solar Radiation (W/m^2)	Daily Mean Wind Direction (°)	Daily Mean Wind Speed (m/s)	Daily Total Precipitation (mm)	Daily Total Evapotranspiration (mm)
27-Oct	13.0	4.6	-1.1	81.2	97.8	-15.5	194	0.4	0.0	0.4
28-Oct	9.5	0.4	-4.6	87.1	98.3	-19.1	202	0.9	0.0	0.4
29-Oct	6.6	-1.4	-6.7	93.6	98.2	0.4	56	2.0	0.0	0.1
30-Oct	0.9	-0.7	-3.4	92.5	98.6	-3.2	148	0.6	0.0	0.1
31-Oct	0.8	-0.1	-0.7	89.6	98.3	-6.2	16	2.5	0.0	0.0

Appendix A2

Water Quality Data

Table A2.1 Mean daily water quality data collected in the No Net Loss Lake, May 11 to Oct 15, 2018.

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)	Chlorophyll A (µg/L)
11-May-18	11.6	307.57	7.86	10.63	1.53	2.54
12-May-18	11.9	308.33	7.89	10.7	1.47	3.08
13-May-18	12.1	309.11	7.94	10.69	1.39	3.49
14-May-18	12.1	309.28	7.98	10.75	1.38	3.62
15-May-18	12.4	309.34	8.01	10.87	1.26	3.37
16-May-18	12.4	309.81	8.04	10.84	1.21	3.23
17-May-18	12.9	309.49	8.07	10.93	1.21	3.36
18-May-18	13.6	310.07	8.1	11.01	1.19	2.96
19-May-18	14.4	310.05	8.12	11.05	1.14	2.81
20-May-18	15.4	310.21	8.15	10.98	1.07	2.72
21-May-18	16.7	310.57	8.16	10.88	0.98	2.69
22-May-18	17.7	310.79	8.18	10.67	0.92	2.42
23-May-18	18.8	311.02	8.19	10.53	0.82	2.19
24-May-18	20.2	311.08	8.2	10.39	0.69	2.22
25-May-18	20.6	310.8	8.21	10.11	0.69	2.87
26-May-18	19.9	309.86	8.21	10.02	0.71	3.03
27-May-18	19	309.44	8.22	10.07	0.72	2.5
28-May-18	19	308.63	8.24	10.11	0.67	2.58
29-May-18	17.9	307.56	8.24	10.15	0.65	2.75
30-May-18	17.1	307.06	8.23	10.19	0.63	2.97
31-May-18	17	306.51	8.25	10.41	0.61	2.32
1-Jun-18	16.9	305.44	8.26	10.58	0.57	2.56
2-Jun-18	16.6	304.62	8.27	10.59	0.6	2.82
3-Jun-18	16.3	303.77	8.27	10.74	0.56	2.61
4-Jun-18	15.4	303.15	8.27	10.81	0.59	2.9
5-Jun-18	14.7	302.24	8.28	10.78	0.6	2.71
6-Jun-18	14.7	301.5	8.29	10.97	0.59	2.09
7-Jun-18	15.5	299.83	8.29	10.97	0.72	1.82
8-Jun-18	17	297.01	8.33	10.85	0.73	2.24
9-Jun-18	17.8	295.81	8.35	11.03	0.69	2.5
10-Jun-18	18.1	295.48	8.36	10.64	0.67	1.76
11-Jun-18	17.2	295.18	8.38	10.31	0.71	1.52
12-Jun-18	16.5	293.56	8.39	10.37	0.72	1.58
13-Jun-18	16	292.33	8.39	10.5	0.74	1.58
14-Jun-18	15.6	290.69	8.4	10.71	0.74	2.09
15-Jun-18	16.2	288.94	8.42	11.24	0.71	2.52
16-Jun-18	17.6	287.49	8.44	11.58	0.68	2.97
17-Jun-18	18.3	285.63	8.45	11.56	0.66	3.15
18-Jun-18	19.2	284.29	8.46	11.52	0.64	3.04
19-Jun-18	20.2	282.85	8.47	11.31	0.62	2.93
20-Jun-18	21.1	281.21	8.47	11.27	0.59	3.08
21-Jun-18	22.3	279.85	8.47	11.07	0.57	3.13

Table A2.1 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)	Chlorophyll A (µg/L)
22-Jun-18	22.40	278.06	8.48	11.06	0.56	3.09
23-Jun-18	22.70	275.46	8.49	10.90	0.57	3.19
24-Jun-18	22.90	272.01	8.48	10.58	0.57	3.14
25-Jun-18	23.20	268.74	8.50	10.84	0.59	3.09
26-Jun-18	22.30	267.92	8.49	10.38	0.63	2.55
27-Jun-18	20.70	265.43	8.47	10.38	0.65	1.37
28-Jun-18	19.90	262.72	8.46	10.54	0.64	2.08
29-Jun-18	19.90	260.71	8.46	10.65	0.63	2.24
30-Jun-18	20.20	258.03	8.48	11.18	0.59	2.46
1-Jul-18	20.70	256.45	8.49	11.36	0.56	2.61
2-Jul-18	20.40	252.93	8.49	11.46	0.57	1.68
3-Jul-18	20.00	250.78	8.48	11.19	0.61	1.52
4-Jul-18	20.20	249.78	8.50	11.39	0.60	2.48
5-Jul-18	20.60	249.96	8.54	11.65	0.60	2.35
6-Jul-18	21.20	248.18	8.54	11.24	0.59	2.64
7-Jul-18	20.70	245.49	8.53	10.69	0.64	1.90
8-Jul-18	19.70	245.59	8.54	11.09	0.67	1.98
9-Jul-18	20.00	245.77	8.55	11.42	0.63	2.58
10-Jul-18	20.70	243.95	8.57	11.44	0.62	2.55
11-Jul-18	21.40	241.77	8.59	11.41	0.60	2.91
12-Jul-18	21.70	240.83	8.57	11.06	0.51	3.24
13-Jul-18	21.40	240.36	8.59	11.28	0.56	2.39
14-Jul-18	20.60	239.00	8.61	11.45	0.62	1.44
15-Jul-18	20.20	239.18	8.60	11.75	0.59	2.13
16-Jul-18	20.50	237.06	8.61	11.85	0.58	2.50
17-Jul-18	21.30	233.60	8.66	12.20	0.54	2.44
18-Jul-18	21.50	231.08	8.68	12.30	0.51	2.44
19-Jul-18	21.30	229.09	8.64	12.30	0.73	1.54
20-Jul-18	21.30	227.59	8.64	12.13	0.50	1.65
21-Jul-18	21.20	225.00	8.63	11.69	0.45	1.89
22-Jul-18	20.00	226.41	8.55	10.94	0.49	2.31
23-Jul-18	19.00	229.97	8.49	10.44	0.57	2.63
24-Jul-18	18.50	229.88	8.47	10.37	0.53	2.41
25-Jul-18	19.00	187.59	8.53	10.88	0.25	1.90
26-Jul-18	19.90	226.39	8.59	11.44	0.13	1.55
27-Jul-18	20.90	224.63	8.64	11.73	0.13	1.53
28-Jul-18	21.60	215.00	8.68	11.74	0.09	1.58
29-Jul-18	21.80	171.19	8.69	11.62	0.08	1.64
30-Jul-18	21.70	214.76	8.70	11.53	0.08	1.68
31-Jul-18	21.60	213.16	8.71	11.48	0.11	1.65
1-Aug-18	22.00	211.61	8.74	11.76	0.10	1.41
2-Aug-18	22.50	208.05	8.77	12.04	0.09	1.46

Table A2.1 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)	Chlorophyll A (µg/L)
3-Aug-18	22.70	207.97	8.79	11.79	0.12	1.74
4-Aug-18	21.80	210.05	8.76	11.27	0.12	1.89
5-Aug-18	21.50	209.07	8.78	11.42	0.13	1.67
6-Aug-18	21.80	209.94	8.78	11.33	0.11	1.58
7-Aug-18	21.90	207.99	8.79	11.47	0.12	1.90
8-Aug-18	22.40	206.95	8.82	11.62	0.14	1.90
9-Aug-18	22.60	205.19	8.83	11.43	0.13	1.99
10-Aug-18	22.40	206.69	8.82	11.11	0.15	2.58
11-Aug-18	21.80	207.00	8.80	11.25	0.25	2.77
12-Aug-18	21.10	206.30	8.80	11.50	0.24	2.90
13-Aug-18	20.40	205.78	8.80	11.67	0.37	3.71
14-Aug-18	20.00	208.29	8.78	11.03	0.61	4.31
15-Aug-18	20.10	209.13	8.74	11.16	0.16	3.69
16-Aug-18	19.90	209.71	8.74	11.21	0.12	3.39
17-Aug-18	20.40	208.93	8.78	11.53	0.11	3.31
18-Aug-18	20.00	208.63	8.78	11.43	0.13	3.00
19-Aug-18	19.70	209.42	8.76	11.27	0.12	3.10
20-Aug-18	19.60	209.53	8.77	11.39	0.15	2.93
21-Aug-18	19.50	209.69	8.78	11.37	0.10	2.77
22-Aug-18	19.10	210.89	8.74	10.92	0.11	2.09
23-Aug-18	17.90	214.03	8.64	10.29	0.19	1.76
24-Aug-18	17.10	217.24	8.55	9.86	0.27	1.43
25-Aug-18	16.30	217.97	8.50	9.63	0.35	1.61
26-Aug-18	15.80	218.90	8.49	9.75	0.35	1.38
27-Aug-18	15.40	218.94	8.49	9.92	0.37	1.88
28-Aug-18	15.20	219.11	8.50	10.07	0.35	1.66
29-Aug-18	14.80	219.86	8.47	10.04	0.33	1.17
30-Aug-18	14.60	220.23	8.45	9.95	0.36	0.80
31-Aug-18	14.60	220.94	8.41	9.77	0.35	1.60
1-Sep-18	14.50	221.63	8.42	9.95	0.32	2.47
2-Sep-18	14.40	222.95	8.41	10.07	0.30	1.52
3-Sep-18	14.00	223.62	8.40	10.26	0.32	1.03
4-Sep-18	13.30	225.47	8.38	10.26	0.36	1.43
5-Sep-18	13.10	226.88	8.40	10.60	0.34	1.30
6-Sep-18	12.80	227.09	8.40	10.71	0.34	1.41
7-Sep-18	12.70	227.45	8.39	10.76	0.35	1.53
8-Sep-18	12.50	227.53	8.38	10.85	0.38	0.67
9-Sep-18	12.00	228.62	8.29	10.46	0.43	0.72
10-Sep-18	11.60	230.20	8.31	10.62	0.44	0.70
11-Sep-18	11.20	230.75	8.31	10.78	0.42	0.71
12-Sep-18	10.40	231.76	8.31	10.82	0.46	0.52
13-Sep-18	10.10	232.29	8.33	11.06	0.45	0.82

Table A2.1 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)	Chlorophyll A (µg/L)
14-Sep-18	9.70	233.40	8.34	11.25	0.44	0.80
15-Sep-18	9.70	234.59	8.34	11.40	0.45	1.46
16-Sep-18	9.40	234.60	8.35	11.48	0.42	1.86
17-Sep-18	9.30	234.73	8.36	11.66	0.44	1.40
18-Sep-18	9.20	235.62	8.37	11.82	0.43	1.18
19-Sep-18	9.30	236.47	8.36	11.84	0.44	1.48
20-Sep-18	9.00	237.40	8.34	11.83	0.40	1.98
21-Sep-18	8.80	238.09	8.35	11.96	0.41	2.01
22-Sep-18	8.30	238.37	8.35	12.08	0.40	1.96
23-Sep-18	7.90	239.44	8.35	12.13	0.39	2.28
24-Sep-18	7.70	240.10	8.35	12.14	0.40	2.22
25-Sep-18	7.50	240.00	8.35	12.12	0.39	2.25
26-Sep-18	7.60	240.37	8.33	12.07	0.39	2.34
27-Sep-18	7.20	241.02	8.32	12.02	0.42	2.31
28-Sep-18	6.90	242.26	8.32	12.12	0.42	2.13
29-Sep-18	6.50	242.46	8.32	12.17	0.42	2.22
30-Sep-18	6.20	243.16	8.32	12.27	0.42	2.26
1-Oct-18	5.90	244.28	8.33	12.39	0.40	2.37
2-Oct-18	5.40	245.02	8.32	12.39	0.40	2.30
3-Oct-18	5.00	245.09	8.33	12.44	0.42	2.35
4-Oct-18	4.60	245.58	8.35	12.63	0.41	2.29
5-Oct-18	4.10	246.21	8.33	12.66	0.42	2.20
6-Oct-18	3.70	246.19	8.35	12.79	0.42	2.40
7-Oct-18	3.50	246.70	8.36	12.94	0.41	2.26
8-Oct-18	3.40	247.23	8.36	13.04	0.39	2.16
9-Oct-18	3.70	248.39	8.37	13.19	0.38	2.03
10-Oct-18	4.00	248.67	8.40	13.54	0.36	1.90
11-Oct-18	4.10	247.78	8.42	13.74	0.36	2.11
12-Oct-18	4.20	247.17	8.41	13.63	0.33	2.34
13-Oct-18	3.90	248.13	8.40	13.59	0.35	2.22
14-Oct-18	3.80	248.84	8.41	13.75	0.35	2.28
15-Oct-18	3.70	249.69	8.40	13.70	0.38	2.23

Table A2.2 Mean daily water quality data collected from Creek A (IC-1), May 10 to November 21, 2018.

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
10-May-18	5.5	313.47	8.14	12.31	2.75
11-May-18	5.2	313.97	8.14	12.47	3.75
12-May-18	5.6	314.77	8.14	12.27	11.71
13-May-18	5	311.29	8.15	12.6	4.51
14-May-18	4.4	314.42	8.15	12.79	0.31
15-May-18	5.3	314.46	8.17	12.46	2.81
16-May-18	5.4	314.4	8.19	12.58	2.36
17-May-18	5.1	314.9	8.19	12.73	4.41
18-May-18	5.1	315.06	8.18	12.74	3.06
19-May-18	5.8	314.95	8.2	12.41	6.62
20-May-18	6.1	315.41	8.2	12.23	3.34
21-May-18	6.4	316.08	8.2	12.13	1.95
22-May-18	6.9	316.31	8.21	12.02	1.71
23-May-18	7.2	317.25	8.2	11.9	1.51
24-May-18	7.3	318.1	8.2	11.82	1.36
25-May-18	7.1	319.87	8.17	11.86	1.35
26-May-18	6.8	318.05	8.22	11.96	1.31
27-May-18	6.7	316.91	8.24	12.11	1.11
28-May-18	6.7	316.99	8.24	12.07	3.84
29-May-18	5.9	316.4	8.26	12.36	1.8
30-May-18	5.5	316.09	8.26	12.56	0.03
31-May-18	5.7	315.69	8.27	12.52	9.09
1-Jun-18	5.4	315.82	8.26	12.62	-0.03
2-Jun-18	5.7	314.43	8.25	12.5	0.33
3-Jun-18	6	310.87	8.29	12.45	0.01
4-Jun-18	5	306.41	8.29	12.72	0.56
5-Jun-18	5.2	304.97	8.29	12.61	0.47
6-Jun-18	5.2	304.9	8.29	12.65	0.65
7-Jun-18	6	305.9	8.29	12.38	0.66
8-Jun-18	6.6	308.23	8.26	12.23	0.16
9-Jun-18	7.3	308.45	8.25	12.02	-0.1
10-Jun-18	7.2	309.18	8.23	11.94	0.8
11-Jun-18	6.7	309.49	8.23	12.02	0.12
12-Jun-18	6.2	307.23	8.2	12.26	1.97
13-Jun-18	5.8	302.4	8.2	12.51	1.05
14-Jun-18	5.8	300.88	8.19	12.57	0.3
15-Jun-18	6	301.54	8.18	12.52	1.12
16-Jun-18	6.7	306.27	8.18	12.37	4.43
17-Jun-18	7.1	308.09	8.17	12.2	0.25
18-Jun-18	7.8	309.79	8.17	12	0.39
19-Jun-18	7.8	310.89	8.15	11.98	0.93
20-Jun-18	8.4	311.72	8.15	11.78	0.46

Table A2.2 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
21-Jun-18	8.6	312.45	8.15	11.7	-0.06
22-Jun-18	8.3	312.64	8.15	11.74	-0.12
23-Jun-18	8.4	313.89	8.11	11.71	1.2
24-Jun-18	8.8	313.74	8.13	11.61	0.45
25-Jun-18	8.8	312.81	8.14	11.54	0.79
26-Jun-18	8.3	311.77	8.15	11.64	0.28
27-Jun-18	7.7	310.06	8.15	11.78	1.56
28-Jun-18	7.8	306.11	8.1	11.79	2.01
29-Jun-18	8	305.14	8.08	11.79	1.27
30-Jun-18	7.8	306.25	8.1	11.8	1.44
1-Jul-18	8	307.39	8.1	11.74	4.66
2-Jul-18	7.9	307.02	8.13	11.81	1.8
3-Jul-18	7.9	308.92	8.11	11.9	1.08
4-Jul-18	7.9	308.95	8.11	11.95	11.89
5-Jul-18	8	307.88	8.11	11.91	12.91
6-Jul-18	8.3	310.04	8.1	11.67	7.99
7-Jul-18	7.8	309.16	8.14	11.77	4.45
8-Jul-18	7.3	308.09	8.13	12.01	4.8
9-Jul-18	7.9	308.19	8.11	11.82	10.24
10-Jul-18	8.4	308.47	8.11	11.62	4.99
11-Jul-18	8.7	308.47	8.11	11.51	16.38
12-Jul-18	8.1	308.21	8.08	11.7	11.55
13-Jul-18	7.9	308.06	8.09	11.79	10.61
14-Jul-18	7.8	306.89	8.14	11.83	21.96
15-Jul-18	7.7	305.51	8.14	11.87	41.45
16-Jul-18	7.9	307.1	8.09	11.73	22.69
17-Jul-18	8.3	307.81	8.09	11.6	29.23
18-Jul-18	8	308.02	8.07	11.71	23.93
19-Jul-18	8.5	307.78	8.13	11.62	2.83
20-Jul-18	8.2	308.91	8.13	11.69	0.35
21-Jul-18	8.7	307.9	8.03	11.46	6.35
22-Jul-18	8.6	298.91	8.05	11.56	1.74
23-Jul-18	8.3	295.51	8.07	11.75	0.93
24-Jul-18	8.3	290.67	8.04	11.77	0.59
25-Jul-18	8	296.48	8.02	11.83	0.51
26-Jul-18	8.4	302.05	8.03	11.68	0.46
27-Jul-18	8.7	304.12	8.05	11.56	0.41
28-Jul-18	9.1	304.58	8.06	11.42	0.35
29-Jul-18	9.4	302.53	8.09	11.37	0.35
30-Jul-18	8.8	306.16	8.07	11.52	0.39
31-Jul-18	8.5	305.41	8.1	11.64	0.35
1-Aug-18	8.5	307.15	8.05	11.5	0.31

Table A2.2 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
2-Aug-18	8.6	307.09	8.06	11.4	0.32
3-Aug-18	9	306.33	8.11	11.23	0.46
4-Aug-18	9.1	305.74	8.15	11.33	0.36
5-Aug-18	8.4	305.57	8.1	11.52	0.28
6-Aug-18	8.6	306.93	8.06	11.36	0.37
7-Aug-18	8.8	305.99	8.09	11.3	0.29
8-Aug-18	9	305.52	8.11	11.25	0.29
9-Aug-18	9	304.53	8.1	11.26	0.31
10-Aug-18	8.9	305.62	8.09	11.26	0.34
11-Aug-18	8.6	303.88	8.16	11.46	0.31
12-Aug-18	7.7	302.06	8.15	11.76	0.32
13-Aug-18	7.5	300.58	8.16	11.73	0.37
14-Aug-18	8.5	300.31	8.13	11.29	0.34
15-Aug-18	8.6	301.05	8.16	11.35	1.06
16-Aug-18	7.8	304.34	8.16	11.69	1.29
17-Aug-18	8.2	305.79	8.15	11.52	1.28
18-Aug-18	8.2	303.37	8.17	11.62	2.2
19-Aug-18	8	304.79	8.15	11.76	2.03
20-Aug-18	7.6	306.81	8.13	11.86	1.97
21-Aug-18	9.1	-	8.1	11.31	4.63
22-Aug-18	8.6	-	8.14	11.31	1.3
23-Aug-18	7.3	-	8.13	11.87	1.55
24-Aug-18	7.1	-	8.11	11.93	2.09
25-Aug-18	6.6	-	8.13	12.09	1.4
26-Aug-18	6.2	-	8.09	12.23	2.4
27-Aug-18	5.8	-	8.09	12.44	2.72
28-Aug-18	6.6	-	8.06	12.04	2.73
29-Aug-18	6.5	-	8.05	12.01	2.72
30-Aug-18	7.1	-	8.03	11.78	3.93
31-Aug-18	7.4	-	8.01	11.74	3.28
1-Sep-18	7.1	-	8.04	11.84	2.97
2-Sep-18	7.2	296.13	8.01	11.88	7.49
3-Sep-18	6.2	288.03	8.03	12.25	3.6
4-Sep-18	5.6	291.41	8.05	12.53	3.7
5-Sep-18	6	290.22	8.04	12.43	4.6
6-Sep-18	5.1	276.58	8.01	12.8	1.87
7-Sep-18	5.3	300.38	7.97	12.6	1.39
8-Sep-18	6	311.29	7.95	12.29	2.17
9-Sep-18	6	312.14	8	12.35	1.56
10-Sep-18	5.3	309.8	7.99	12.54	1.48
11-Sep-18	5.2	308.9	8	12.57	1.36
12-Sep-18	4.8	303.31	8	12.82	1.4

Table A2.2 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
13-Sep-18	4.7	302.68	7.99	12.86	1.4
14-Sep-18	4.2	306.09	7.99	13.05	1.37
15-Sep-18	4	307.6	7.97	13.15	1.41
16-Sep-18	3.7	309.02	7.96	13.24	1.45
17-Sep-18	3.8	310.14	7.95	13.16	1.31
18-Sep-18	4.5	307.92	7.96	12.91	2.25
19-Sep-18	4.5	310.66	7.96	13.02	1.11
20-Sep-18	4.2	311.35	7.97	13.32	0.27
21-Sep-18	3.2	311.69	7.95	13.69	0.1
22-Sep-18	3	311.61	7.95	13.76	0.13
23-Sep-18	3.2	311.26	7.96	13.6	0.13
24-Sep-18	3.8	311.51	7.96	13.42	0.18
25-Sep-18	3.6	311.6	7.96	13.53	0.28
26-Sep-18	4.5	311.28	7.97	13.28	0.4
27-Sep-18	3.7	311.27	7.98	13.68	0.11
28-Sep-18	3.7	310.79	7.99	13.65	0.16
29-Sep-18	3.6	310.36	7.99	13.75	0.22
30-Sep-18	3.3	310.73	7.98	13.82	0.35
1-Oct-18	3.4	310.83	7.98	13.72	0.4
2-Oct-18	2.8	310.59	7.98	13.88	0.44
3-Oct-18	2.9	310.2	7.98	13.9	0.44
4-Oct-18	2.3	311.13	7.98	14.11	0.32
5-Oct-18	2.5	310.43	7.98	14.03	0.33
6-Oct-18	2.4	311.05	7.98	14.13	0.22
7-Oct-18	2.6	310.9	7.99	14.17	0.25
8-Oct-18	1.7	311.88	7.98	14.51	0.13
9-Oct-18	1.4	312.74	7.97	14.63	0.17
10-Oct-18	1.6	312.86	7.98	14.5	0.16
11-Oct-18	2.5	312.26	7.99	13.99	0.22
12-Oct-18	2.5	310.82	8	13.96	0.3
13-Oct-18	2.3	311.8	8	14.21	0.19
14-Oct-18	2.1	311.89	7.99	14.16	0.19
15-Oct-18	2.8	311.2	8	13.94	0.26
16-Oct-18	2.5	311.57	7.99	14.14	0.25
17-Oct-18	2.9	310.96	7.99	13.83	0.37
18-Oct-18	3.5	310.48	8.01	13.67	0.34
19-Oct-18	2.9	309.58	8.01	14.06	0.31
20-Oct-18	3	309.09	8.02	13.81	0.31
21-Oct-18	3	308.83	8.02	13.9	0.24
22-Oct-18	2.2	308.91	8.01	14.22	0.27
23-Oct-18	2.6	309.48	8.02	13.98	0.25
24-Oct-18	2.2	310.44	8	14.08	0.27

Table A2.2 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
25-Oct-18	2.2	310.34	8.01	14.07	0.41
26-Oct-18	2.8	309.99	8.03	13.85	0.4
27-Oct-18	2.2	310.46	8.03	14.06	0.34
28-Oct-18	1.8	310.73	8.02	14.26	0.37
29-Oct-18	2.3	310.38	8.03	14.07	0.4
30-Oct-18	2.7	310.39	8.03	14.01	0.43
31-Oct-18	2.5	310.5	8.04	14.02	0.37
1-Nov-18	2.2	310.09	8.05	14.24	-0.58
2-Nov-18	2.2	310.04	8.04	14.17	-0.73
3-Nov-18	2.3	310.11	8.05	14.09	-0.72
4-Nov-18	1.8	310.02	8.06	14.29	-0.73
5-Nov-18	1.4	310.07	8.05	14.56	-0.72
6-Nov-18	1.2	310.84	8.04	14.72	-0.72
7-Nov-18	0.9	312.11	8.04	14.84	-0.72
8-Nov-18	0.3	314.92	8.02	15.1	-0.63
9-Nov-18	0.8	313.77	8.04	14.7	-0.68
10-Nov-18	1.2	313.12	8.04	14.66	-0.66
11-Nov-18	1.1	313.69	8.04	14.83	-0.73
12-Nov-18	1	314.13	8.03	14.75	-0.71
13-Nov-18	1.5	313.55	8.04	14.47	-0.73
14-Nov-18	1.5	313.3	8.04	14.39	-0.74
15-Nov-18	0.8	313.93	8.04	14.84	-0.73
16-Nov-18	0.4	314.96	8.03	15.11	-0.67
17-Nov-18	0.2	311.51	8	15.04	-0.44
18-Nov-18	0.4	309.5	8.01	14.91	-0.65
19-Nov-18	0.8	314.04	8.01	14.7	-0.66
20-Nov-18	1.2	313	8.02	14.58	-0.72
21-Nov-18	1.3	313.08	8.03	14.4	-0.7

Table A2.3 Mean daily water quality data collected from the outlet channel (OC-1), May 10 to November 26, 2018.

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
10-May-18	12.6	274.73	7.8	9.62	3.85
11-May-18	12.4	268.01	7.81	9.29	3.91
12-May-18	13.3	276.64	7.83	9.18	3.56
13-May-18	12.3	280.51	7.9	9.59	3.43
14-May-18	11.7	280.06	7.92	10.03	2.65
15-May-18	13.2	277.77	7.92	9.68	2.68
16-May-18	13.3	280.06	7.97	9.93	2.15
17-May-18	13.4	280.59	7.97	10.03	1.76
18-May-18	14	284.32	7.95	9.9	1.94
19-May-18	14.8	289.81	7.94	9.68	2.37
20-May-18	15.6	286.24	7.95	9.58	2.03
21-May-18	17.1	292.58	7.97	9.4	1.55
22-May-18	18.1	305.61	7.93	8.89	1.42
23-May-18	19.1	304.69	7.95	8.91	1.09
24-May-18	20.5	305.65	7.94	8.51	2.85
25-May-18	20.5	306.11	7.94	8.33	0.63
26-May-18	19.2	311.35	7.93	8.3	0.88
27-May-18	18.7	308.77	8	9	0.57
28-May-18	18.4	303.47	8.02	9.13	1.86
29-May-18	17.6	294.17	8.1	9.82	1.03
30-May-18	15.9	304.51	7.94	9.02	5.2
31-May-18	15.2	294.98	7.97	9.59	1.34
1-Jun-18	14.1	294.51	8.02	9.69	3.53
2-Jun-18	15.2	294.17	8.01	9.39	2.31
3-Jun-18	15.2	292.95	8.07	10.14	1.21
4-Jun-18	15	290.7	8.09	10.3	8.11
5-Jun-18	14.4	290.5	8.08	10.43	1.37
6-Jun-18	13.8	288.11	7.96	9.74	5.42
7-Jun-18	16.8	289.34	7.89	9.22	2.73
8-Jun-18	17.5	295.57	7.78	8.42	0.86
9-Jun-18	17.7	292.47	7.99	9.71	0.4
10-Jun-18	18.3	289.72	8.16	10.45	0.26
11-Jun-18	17.2	290.04	8.08	9.81	0.5
12-Jun-18	15.4	287.07	8.02	9.49	0.65
13-Jun-18	14.9	285.67	8	9.66	0.83
14-Jun-18	14.8	289.37	7.89	9.31	0.91
15-Jun-18	17	289.75	7.77	8.23	0.48
16-Jun-18	17.9	287.99	7.93	9.3	0.77
17-Jun-18	18.9	282.81	8.11	10.67	0.74
18-Jun-18	20.5	286.51	7.71	7.27	0.58
19-Jun-18	20.8	286.43	7.61	6.3	0.23
20-Jun-18	22.6	286.69	7.56	5.49	0.24

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
21-Jun-18	23.1	284.84	7.55	5.21	0.19
22-Jun-18	22.3	282.57	7.59	5.67	0.22
23-Jun-18	22.5	276.84	7.85	7.58	1.13
24-Jun-18	23.7	269.48	8.08	9.43	0.97
25-Jun-18	23.3	272.19	7.75	7	1.43
26-Jun-18	21.3	268.51	7.72	6.88	0.48
27-Jun-18	18.8	274.27	7.84	7.89	0.81
28-Jun-18	19.7	269.1	8.11	10.25	0.91
29-Jun-18	20.2	269.76	8.13	10.56	1.17
30-Jun-18	20.3	297.43	7.82	8.15	2.06
1-Jul-18	21.1	290.48	7.71	6.96	1.95
2-Jul-18	20	280.5	7.73	6.94	1.3
3-Jul-18	19.8	296.17	7.89	8.44	3.82
4-Jul-18	20.7	321.55	7.77	7.72	2
5-Jul-18	20.7	294.21	7.7	7.01	1.4
6-Jul-18	21.1	274.99	7.73	6.95	1.1
7-Jul-18	18.8	270.31	7.79	7.36	1.16
8-Jul-18	18.5	259.67	7.92	8.83	1.05
9-Jul-18	20.1	258.43	7.89	8.45	1.02
10-Jul-18	20.6	255.27	8	9.3	1.74
11-Jul-18	22.1	244.46	8.26	11.06	2.38
12-Jul-18	21.6	245.68	8.06	9.04	2.67
13-Jul-18	20.9	246.03	7.92	8.04	2.18
14-Jul-18	19.8	243.73	8.12	9.69	2.11
15-Jul-18	20.3	239.32	8.3	11.48	2.24
16-Jul-18	20.8	240.97	8.13	9.88	2.46
17-Jul-18	22	245.56	7.88	8.04	2.42
18-Jul-18	21.6	247.59	7.92	7.37	1.48
19-Jul-18	21.4	243.78	8.17	7.76	0.12
20-Jul-18	20.8	237.78	8.25	8.07	0.14
21-Jul-18	20.7	274.73	8.17	7.87	8.94
22-Jul-18	18.6	291.52	8.37	9.59	1.35
23-Jul-18	17.7	279.13	8.32	9.56	1.62
24-Jul-18	18.5	238.41	8.49	10.7	1.14
25-Jul-18	19	245.05	8.39	10.1	1.05
26-Jul-18	20.2	246.39	8.27	9.18	0.86
27-Jul-18	21.1	246.22	8.16	8.25	0.97
28-Jul-18	21.1	240.42	8.31	9.22	1.24
29-Jul-18	22.1	225.47	8.6	11.05	0.65
30-Jul-18	21.1	229.19	8.3	8.45	1.14
31-Jul-18	21.1	229.4	8.31	8.58	0.66
1-Aug-18	21.5	230.35	8.26	8.26	0.58

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
2-Aug-18	22.3	230.45	8.24	8.05	0.54
3-Aug-18	22.5	230.02	8.23	7.86	0.63
4-Aug-18	20.7	224.87	8.47	9.53	2.2
5-Aug-18	21.5	219.35	8.68	10.61	4.54
6-Aug-18	21.5	223.49	8.42	8.95	3.6
7-Aug-18	22	226.05	8.33	8.34	2.87
8-Aug-18	22.5	228.87	8.24	7.75	2.55
9-Aug-18	21.9	227.61	8.26	7.72	2.4
10-Aug-18	21.3	224.87	8.24	7.65	2.35
11-Aug-18	20.7	218.16	8.52	9.85	4.47
12-Aug-18	20.6	212.84	8.73	11.11	2.26
13-Aug-18	18.7	220.57	8.51	9.42	2.2
14-Aug-18	19.9	227.75	8.43	9.1	2.03
15-Aug-18	20	223.98	8.49	9.42	2.22
16-Aug-18	19.9	217.32	8.73	10.5	2.02
17-Aug-18	20.7	216.62	8.69	9.99	2.03
18-Aug-18	19.2	222.02	8.52	8.93	2.08
19-Aug-18	19	217.38	8.5	8.82	1.99
20-Aug-18	18.7	217.25	8.52	9.07	1.91
21-Aug-18	19.3	222.19	8.46	8.81	1.93
22-Aug-18	17.5	226.6	8.37	8.42	1.96
23-Aug-18	15.8	220.8	8.46	9.27	2.22
24-Aug-18	15.2	222.48	8.42	9.19	2.17
25-Aug-18	14.7	221.66	8.48	9.77	2.09
26-Aug-18	14.4	221.83	8.45	9.72	2.05
27-Aug-18	14.3	222.65	8.43	9.75	2.14
28-Aug-18	14.6	223.77	8.4	9.63	2.27
29-Aug-18	13.8	225.55	8.31	9.31	2.18
30-Aug-18	13.9	228.99	8.27	9.14	2.48
31-Aug-18	14.7	227.84	8.37	9.73	2.32
1-Sep-18	14.1	230.27	8.33	9.71	2.28
2-Sep-18	14.1	227.92	8.35	9.86	2.2
3-Sep-18	12.4	229.81	8.3	9.8	2.24
4-Sep-18	12.2	230.4	8.35	10.22	2.16
5-Sep-18	12.5	231.21	8.35	10.32	4.88
6-Sep-18	11.7	229.87	8.39	10.65	2.18
7-Sep-18	12.1	230.22	8.4	10.64	2.47
8-Sep-18	12.6	229.35	8.44	10.9	2.23
9-Sep-18	11.6	234.5	8.37	10.71	2.2
10-Sep-18	11.4	231.46	8.41	10.86	2.22
11-Sep-18	10.6	234.15	8.4	10.99	2.25
12-Sep-18	9.7	234.23	8.44	11.35	2.23

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
13-Sep-18	9.4	233.23	8.45	11.43	2.23
14-Sep-18	9.1	234.49	8.44	11.38	2.41
15-Sep-18	9.3	234.32	8.46	11.59	2.28
16-Sep-18	8.3	235.31	8.45	11.62	2.27
17-Sep-18	-	-	-	-	-
18-Sep-18	9.4	242.77	8.64	11.46	0.87
19-Sep-18	9.1	239.49	8.67	11.51	0.92
20-Sep-18	8	241.31	8.68	11.76	0.92
21-Sep-18	7.6	238.78	8.72	12.02	0.89
22-Sep-18	7.2	239.58	8.72	12.06	0.92
23-Sep-18	6.9	241.24	8.72	12.12	0.91
24-Sep-18	7.5	242.19	8.71	12.08	0.97
25-Sep-18	7.2	242.4	8.72	12.2	0.96
26-Sep-18	7.6	243.31	8.7	12.23	1.45
27-Sep-18	6.8	242.35	8.73	12.65	0.8
28-Sep-18	6.7	242.92	8.73	12.69	0.79
29-Sep-18	5.9	245.2	8.71	12.73	0.86
30-Sep-18	5.9	243.94	8.75	12.82	0.82
1-Oct-18	5.7	245.03	8.76	12.91	0.85
2-Oct-18	5	245.59	8.76	12.97	0.9
3-Oct-18	4.2	246.29	8.76	13.15	0.84
4-Oct-18	4	245.55	8.78	13.36	1.1
5-Oct-18	3.4	249.33	8.75	13.42	1.29
6-Oct-18	3.3	247	8.8	13.65	1.14
7-Oct-18	3.3	247.29	8.79	13.68	1
8-Oct-18	3.1	246.77	8.8	13.76	1.14
9-Oct-18	3.3	247.38	8.8	13.85	1.35
10-Oct-18	3.6	247.99	8.81	14.02	1.22
11-Oct-18	3.8	247.76	8.82	14.04	1.07
12-Oct-18	3.5	248.47	8.8	13.9	1.15
13-Oct-18	3.4	248.21	8.82	14.16	0.97
14-Oct-18	3.8	249.36	8.82	14.12	1.11
15-Oct-18	3.8	249.66	8.81	14.14	1
16-Oct-18	3.8	249.33	8.83	14.36	2.44
17-Oct-18	4.2	249.13	8.83	14.32	0.98
18-Oct-18	4.2	249.79	8.81	14.18	1.07
19-Oct-18	4	251.49	8.79	14.15	1.03
20-Oct-18	4.1	253.1	8.78	14.03	1.07
21-Oct-18	4	253.58	8.77	13.94	1.13
22-Oct-18	3.8	254.09	8.77	14.01	1.08
23-Oct-18	3.6	254.53	8.76	13.95	1.04
24-Oct-18	3.6	254.39	8.77	14.01	1.05

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
25-Oct-18	3.7	255.36	8.76	13.98	1.04
26-Oct-18	3.8	255.89	8.77	14.03	1.03
27-Oct-18	3.5	255.98	8.78	14.14	1.03
28-Oct-18	3.4	256.19	8.79	14.19	1.14
29-Oct-18	3.4	257.24	8.77	14.12	0.99
30-Oct-18	3.3	257.67	8.77	14.23	0.99
31-Oct-18	3.1	259.21	8.76	14.15	0.99
1-Nov-18	2.8	258.56	8.76	14.15	1.05
2-Nov-18	2.8	257.87	8.77	14.16	1.08
3-Nov-18	2.6	258.82	8.76	14.16	1
4-Nov-18	1.7	262.58	8.72	14.08	1.05
5-Nov-18	1.1	262.87	8.73	14.22	1.09
6-Nov-18	1	265.77	8.74	14.41	1.03
7-Nov-18	1.1	272.85	8.74	14.72	1.01
8-Nov-18	1	279.39	8.73	15.02	1
9-Nov-18	1	279.51	8.74	15.01	1
10-Nov-18	0.9	277.76	8.74	14.92	0.99
11-Nov-18	0.9	278.4	8.74	15.02	0.99
12-Nov-18	0.8	279.2	8.74	15.03	0.99
13-Nov-18	0.9	278.05	8.74	14.95	0.98
14-Nov-18	0.8	278.84	8.73	14.87	0.97
15-Nov-18	0.7	280.03	8.74	15	0.95
16-Nov-18	0.7	282.68	8.74	15.1	0.96
17-Nov-18	0.7	283.84	8.74	15.17	3.1
18-Nov-18	0.7	283.13	8.74	15.12	0.96
19-Nov-18	0.7	283.32	8.73	15.06	0.94
20-Nov-18	0.6	282.17	8.73	14.95	0.94
21-Nov-18	0.6	281.08	8.73	14.82	0.95
22-Nov-18	0.7	279.59	8.73	14.74	0.92
23-Nov-18	0.6	280.67	8.73	14.7	0.89
24-Nov-18	0.6	280.45	8.73	14.7	0.88
25-Nov-18	0.7	280.03	8.73	14.67	0.87
26-Nov-18	0.6	280.52	8.72	14.58	0.87

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
10-May-18	5.8	343.21	8.23	12.3	6.37
11-May-18	6.5	342.9	8.25	12.19	5.74
12-May-18	6.8	343.7	8.26	12.02	5.67
13-May-18	6	343.79	8.26	12.31	6.17
14-May-18	5.6	345.07	8.27	12.42	4.5
15-May-18	6.4	345.46	8.28	12.11	4.39
16-May-18	6.2	345.87	8.28	12.28	3.83
17-May-18	6.1	346.66	8.29	12.32	3.78
18-May-18	6.3	347.86	8.29	12.26	3.97
19-May-18	7	348.78	8.3	11.96	4.84
20-May-18	7.2	349.11	8.3	11.8	4.95
21-May-18	7.3	350.13	8.3	11.71	4.42
22-May-18	7.6	350.9	8.32	11.64	3.79
23-May-18	7.8	351.82	8.32	11.54	3.63
24-May-18	7.6	352.85	8.32	11.51	3.44
25-May-18	7.4	354.41	8.32	11.46	4.74
26-May-18	7.2	356.09	8.35	11.51	10.68
27-May-18	7.2	356.53	8.36	11.64	5.09
28-May-18	11	342	8.35	10.71	8.35
29-May-18	10.9	336.66	8.35	10.51	4.22
30-May-18	6.4	356.38	8.39	11.79	4.14
31-May-18	6.5	358.54	8.41	11.77	3.88
1-Jun-18	6	359.87	8.41	11.89	3.79
2-Jun-18	6.3	360.99	8.42	11.74	3.34
3-Jun-18	9.5	346.05	8.43	11.03	4.51
4-Jun-18	8	346.73	8.42	11.06	3.28
5-Jun-18	7.1	355.58	8.44	11.28	3.85
6-Jun-18	6.2	363.08	8.46	11.59	4.3
7-Jun-18	6.9	364.61	8.47	11.37	4.02
8-Jun-18	7.1	364.98	8.47	11.21	3.79
9-Jun-18	10.8	331.03	8.46	10.5	16.65
10-Jun-18	13.1	290.7	8.42	9.56	134.66
11-Jun-18	7.5	307.83	8.41	10.3	74
12-Jun-18	6.4	315.98	8.39	11.12	172.46
13-Jun-18	6.1	319.75	8.36	11.36	114.89
14-Jun-18	6	318.89	8.34	11.42	159.69
15-Jun-18	6.5	320.26	8.33	11.17	171.89
16-Jun-18	11.3	310.29	8.3	10.79	51.26
17-Jun-18	9.6	317.46	8.32	10.88	9.78
18-Jun-18	7.8	330.59	8.36	11.33	12.28
19-Jun-18	7.5	331.85	8.35	11.4	12.49
20-Jun-18	8	331.95	8.35	11.27	13.82
21-Jun-18	7.8	332.9	8.34	11.33	11.31
22-Jun-18	7.6	333.29	8.34	11.35	36.22

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (μS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
23-Jun-18	11.3	320.72	8.3	10.67	100.52
24-Jun-18	10.3	319.1	8.29	10.74	85.48
25-Jun-18	8.3	330.61	8.3	11.14	218.81
26-Jun-18	7.4	329.75	8.3	11.36	97.44
27-Jun-18	7.4	336.14	8.27	11.27	167.55
28-Jun-18	12.9	306.94	8.18	9.93	244.94
29-Jun-18	10.3	316.53	8.15	10.35	312.25
30-Jun-18	7.7	326.53	8.16	11.33	238.68
1-Jul-18	7.6	324.05	8.17	11.32	123.89
2-Jul-18	7.3	326.93	8.2	11.56	70.71
3-Jul-18	7.7	328.89	8.19	11.55	170.7
4-Jul-18	7.6	334.21	8.17	11.67	41.46
5-Jul-18	7.8	330.47	8.2	11.67	34.62
6-Jul-18	7.8	329.1	8.21	11.53	31.42
7-Jul-18	6.9	329.81	8.22	11.72	29.43
8-Jul-18	6.9	330.94	8.23	11.85	23.97
9-Jul-18	7.8	332.32	8.22	11.66	22.32
10-Jul-18	11.4	319.9	8.22	11.16	67.61
11-Jul-18	14	304.44	8.19	10.49	99.39
12-Jul-18	7.9	330.4	8.18	11.57	70.19
13-Jul-18	7.5	336.88	8.21	11.73	49.24
14-Jul-18	11.5	316.52	8.24	11.23	35.98
15-Jul-18	14.1	301.64	8.25	10.8	16.69
16-Jul-18	8.3	335.78	8.21	11.56	16.77
17-Jul-18	8	343.12	8.22	11.67	17.42
18-Jul-18	7.3	346.78	8.21	11.88	20.69
19-Jul-18	8.1	347.83	8.24	11.76	11.95
20-Jul-18	7.5	352.02	8.26	11.93	1.13
21-Jul-18	8.4	363.79	8.19	11.46	364.83
22-Jul-18	8.8	381.74	8.17	11.27	93.21
23-Jul-18	10.4	342.13	8.19	11.1	56.46
24-Jul-18	14.3	287.62	8.18	10.31	11.95
25-Jul-18	8.1	353.38	8.18	11.57	24.59
26-Jul-18	8.1	356.99	8.21	11.53	20.94
27-Jul-18	8	356.56	8.23	11.44	12.8
28-Jul-18	12.7	313.94	8.23	10.64	13.45
29-Jul-18	12.6	315.66	8.24	10.3	4.38
30-Jul-18	8	352.54	8.26	11.29	8.19
31-Jul-18	7.7	355.26	8.29	11.34	13.24
1-Aug-18	7.7	356.12	8.28	11.13	17.4
2-Aug-18	7.9	356.51	8.29	10.99	94.64
3-Aug-18	8.1	357.19	8.32	10.81	87.79
4-Aug-18	11	324.49	8.28	10.39	155.25
5-Aug-18	10.1	332.83	8.09	10.32	50.68

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
6-Aug-18	7.7	353.61	8.14	10.73	46.11
7-Aug-18	7.9	355.68	8.19	10.64	21.57
8-Aug-18	8.1	356.63	8.23	10.59	22.26
9-Aug-18	7.7	357.1	8.24	10.61	20.63
10-Aug-18	7.5	357.69	8.26	10.55	24.15
11-Aug-18	10.9	319.94	8.2	10.03	72.27
12-Aug-18	8.7	334.83	8.15	10.3	17.24
13-Aug-18	7.5	352.62	8.21	10.48	26.26
14-Aug-18	8.1	353.01	8.24	10.1	10.18
15-Aug-18	9.8	328.32	8.25	10.19	4.06
16-Aug-18	12.3	291.4	8.22	10.4	0.74
17-Aug-18	8.8	330.75	8.19	10.95	1.07
18-Aug-18	7.5	341.76	8.21	11.33	1.18
19-Aug-18	7.2	345.5	8.21	11.49	1.39
20-Aug-18	7	347.34	8.21	11.55	1.23
21-Aug-18	7.4	348.35	8.21	11.37	1.21
22-Aug-18	7	349.1	8.21	11.36	1.28
23-Aug-18	6.5	350.46	8.19	11.54	71.4
24-Aug-18	6.3	345.9	8.19	11.55	24.89
25-Aug-18	6.3	345.47	8.22	11.62	1.58
26-Aug-18	6.2	346.67	8.22	11.65	1.44
27-Aug-18	6	347.47	8.22	11.75	1.32
28-Aug-18	6.5	347.38	8.19	11.52	1.33
29-Aug-18	6.2	352.35	8.2	11.56	1.39
30-Aug-18	6.8	351.19	8.18	11.29	90.32
31-Aug-18	7.6	342.53	8.18	11.14	2.16
1-Sep-18	6.8	346.35	8.19	11.36	2.68
2-Sep-18	6.6	349.18	8.21	11.53	1.8
3-Sep-18	6	352.72	8.19	11.71	9.15
4-Sep-18	5.8	352.61	8.21	11.9	1.57
5-Sep-18	6.1	353.04	8.21	11.84	1.54
6-Sep-18	5.5	353.83	8.19	12.07	1.39
7-Sep-18	8.2	319.76	8.2	11.26	1.82
8-Sep-18	9.3	306.4	8.2	10.8	35.21
9-Sep-18	8.4	312.72	8.19	10.95	1.78
10-Sep-18	7.6	322.31	8.21	11.23	1.17
11-Sep-18	5.9	345.98	8.21	11.71	2.05
12-Sep-18	5.6	346.66	8.21	11.92	1.24
13-Sep-18	5.2	355.33	8.21	12.05	1.25
14-Sep-18	5.1	356.34	8.2	12.12	1.22
15-Sep-18	5.1	356.8	8.19	12.13	1.25
16-Sep-18	4.6	358.61	8.19	12.27	1.27
17-Sep-18	-	-	-	-	-
18-Sep-18	5.5	357.28	8.2	11.96	1.03

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
19-Sep-18	5.3	355.53	8.2	12.04	1.04
20-Sep-18	4.8	354.95	8.21	12.25	1
21-Sep-18	4.4	353.64	8.2	12.4	1.33
22-Sep-18	4.3	355.45	8.21	12.39	1.63
23-Sep-18	4.5	353.93	8.21	12.22	1.18
24-Sep-18	4.9	354.31	8.21	12.12	1.08
25-Sep-18	4.9	353.51	8.21	12.14	1.1
26-Sep-18	5.9	327.75	8.26	11.95	1.48
27-Sep-18	5.5	301.02	8.31	12.16	0.74
28-Sep-18	5.4	314.03	8.29	12.19	0.73
29-Sep-18	4.7	322.03	8.27	12.36	0.78
30-Sep-18	4.6	324.94	8.27	12.4	0.85
1-Oct-18	4.5	330.16	8.26	12.36	0.86
2-Oct-18	4.1	331.53	8.27	12.46	1.27
3-Oct-18	3.9	335.4	8.27	12.56	1.23
4-Oct-18	3.6	336.98	8.27	12.66	2.23
5-Oct-18	3.5	337.96	8.27	12.69	1.5
6-Oct-18	3.6	338.31	8.27	12.73	1.53
7-Oct-18	3.6	338.29	8.27	12.8	5.82
8-Oct-18	3.1	338.37	8.27	12.97	13.78
9-Oct-18	3.1	338.23	8.27	12.98	194.11
10-Oct-18	3.4	337.93	8.27	12.85	23.26
11-Oct-18	3.9	338.2	8.28	12.53	9.96
12-Oct-18	3.7	337.47	8.29	12.58	2.15
13-Oct-18	3.5	337.86	8.3	12.82	1.16
14-Oct-18	3.7	337.9	8.29	12.62	1.81
15-Oct-18	4.1	337.03	8.3	12.52	1.82
16-Oct-18	3.9	326.29	8.32	12.76	1.69
17-Oct-18	4.3	320.08	8.33	12.54	2.86
18-Oct-18	4.6	323.83	8.32	12.43	2.09
19-Oct-18	4	327.5	8.31	12.74	44.77
20-Oct-18	4.3	330.58	8.31	12.45	6.83
21-Oct-18	4.1	332.21	8.31	12.53	2.41
22-Oct-18	3.7	333.89	8.3	12.7	3.35
23-Oct-18	3.9	334.89	8.31	12.55	4.49
24-Oct-18	3.7	335.74	8.3	12.57	6.81
25-Oct-18	3.8	336.12	8.3	12.53	9.11
26-Oct-18	4.2	336.53	8.31	12.39	3.66
27-Oct-18	3.7	336.86	8.3	12.55	6.13
28-Oct-18	3.5	337.19	8.3	12.68	8.39
29-Oct-18	3.8	337.2	8.31	12.56	3.61
30-Oct-18	3.9	337.47	8.31	12.56	0.73
31-Oct-18	3.6	337.68	8.32	12.62	0.66
1-Nov-18	3.3	338.35	8.32	12.79	1.97

Table A2.3 (Cont'd.)

Date	Temp (°C)	Specific Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidy (FNU)
2-Nov-18	3.4	338.37	8.32	12.71	5.64
3-Nov-18	3.4	337.65	8.32	12.68	11.41
4-Nov-18	2.6	339.5	8.32	12.9	3.5
5-Nov-18	2.4	340.35	8.33	13.11	7.55
6-Nov-18	2.3	341.45	8.32	13.2	11.67
7-Nov-18	2.1	343.73	8.33	13.3	17.33
8-Nov-18	1.7	346.97	8.32	13.48	23.45
9-Nov-18	2.1	345.82	8.33	13.13	20.9
10-Nov-18	2.4	344.55	8.33	13.15	19.83
11-Nov-18	2.3	345.25	8.33	13.32	29.81
12-Nov-18	2.3	345.56	8.33	13.21	32.92
13-Nov-18	2.7	344.29	8.33	12.98	31.71
14-Nov-18	2.5	344.89	8.33	12.95	33.99
15-Nov-18	1.9	346.05	8.34	13.34	40.14
16-Nov-18	1.7	347.31	8.33	13.47	48.94
17-Nov-18	1.8	347.35	8.34	13.33	51.53
18-Nov-18	1.9	345.6	8.33	13.22	51.99
19-Nov-18	2.3	344.51	8.33	13.06	51.04
20-Nov-18	2.3	343.19	8.33	13.03	44.9
21-Nov-18	2.3	342.91	8.33	12.92	58.31
22-Nov-18	2.5	343.16	8.33	12.76	51.53
23-Nov-18	2.3	343.8	8.35	12.99	23.33
24-Nov-18	2.3	343.96	8.35	13.07	12.58
25-Nov-18	2.6	343.97	8.34	13	14.2
26-Nov-18	2.6	344.36	8.34	12.92	17.48

Table A2.5 Seasonal concentrations of water quality variables measured in No Net Loss Lake, Creek A and the outlet channel, 2018.

Variables	Lowest Detection Limits	Units	Guideline AESRD[a]		IC-1				OC-1				OC-2				PZ-1			
			Acute	Chronic	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Variables																				
Alkalinity, Phenolphthalein ($CaCO_3$)	2	mg/L	-	20	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	3.1	<2.0	2	<2.0	<2.0	<2.0	<2.0
Total alkalinity	2	mg/L	-	20 (minimum)	**158**	**153**	**161**	**150**	**168**	**153**	**112**	**119**	**177**	**174**	**168**	**172**	**168**	**151**	**117**	**119**
True Colour	2.0	C.U.	-	20% increase	3.4	5.5	7.6	7.5	5.3	4.7	8.2	4.9	4.6	<2.0	2.6	2.2	5.7	4.5	5.5	5.1
Conductivity (EC)	2	µS/cm	-	-	306	293	284	312	328	310	213	263	350	351	321	373	327	296	218	261
Dissolved Organic Carbon	1	mg/L	-	-	2.4	2.7	3.7	4	3.4	3.1	4.6	5	2.6	2	3.1	3.1	3.7	2.7	4.8	5.1
Hardness (as $CaCO_3$)	1.3	mg/L	-	-	148	150	168	157	158	151	114	171	177	177	175	171	153	146	117	118
pH		pH	-	6.5-9.0	**8.22**	**8.34**	**8.19**	**8.03**	**8.22**	**8.19**	**8.09**	**8.29**	**8.28**	**8.37**	**8.31**	**8.36**	**8.19**	**8.24**	**8.11**	**8.24**
Total Dissolved Solids	10	mg/L	-	-	176	178	193	189	185	175	148	148	210	205	236	212	191	183	152	146
Total Organic Carbon	1	mg/L	-	-	2.2	2.5	3.7	3.9	2.6	2.9	4.4	4.6	2	1.9	3.1	3	3.1	3.3	4.3	4.9
Total Suspended Solids	3	mg/L	varies[b]	varies[b]	8.1	<3.0	<3.0	<3.0	5.7	<3.0	<3.0	<3.0	10.3	8.9	<3.0	<3.0	4.6	5.9	<3.0	<3.0
Dissolved Metals																				
Aluminum (Al)	0.001	mg/L	0.1[c]	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0097	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Antimony (Sb)	0.00001	mg/L	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000011	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000012	0.000018
Arsenic (As)	0.00005	mg/L	-	0.005	<0.000050	0.000063	0.000056	0.000059	0.0001	0.000190	0.000245	0.000189	0.000084	0.000150	0.000088	0.000091	0.00016	0.000200	0.00022	0.000199
Barium (Ba)	0.0001	mg/L	-	-	0.0755	0.0836	0.0903	0.0815	0.0771	0.0739	0.0558	0.0612	0.0945	0.115	0.126	0.127	0.0809	0.0780	0.059	0.063
Beryllium (Be)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Bismuth (Bi)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	0.005	mg/L	29	1.5	0.0134	0.0155	0.0152	0.0133	0.0203	0.0323	0.0376	0.0322	0.0164	0.0200	0.0192	0.0212	0.0244	0.0282	0.0326	0.0311
Cadmium (Cd)	0.000005	mg/L	0.00011 to 0.0077[d]	0.00004 to 0.00037[d]	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)	0.05	mg/L	-	-	47	49.8	53.9	49.2	48.1	45.4	32	31.8	55.7	55.4	57.7	52.4	46	44.9	32.9	31.6
Cesium (Cs)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000059	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Chromium (Cr)	0.0005	mg/L	-	0.0089	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)	0.00005	mg/L		0.0013[i]	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000059	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Copper (Cu)	0.0002	mg/L	0.0009 to 0.062[d]	0.007	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.0000050	<0.00020	<0.00020	<0.00020	0.00023
Gallium (Ga)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.00050	<0.000050	<0.000050	<0.000050	<000050
Iron (Fe)	0.03	mg/L	-	-	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.239	<0.030	<0.000050	<0.030	<0.030	<0.030	<0.030
Lead (Pb)	0.00005	mg/L	-	0.001 to 0.007[n]	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000056	<0.000050	<0.00050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium (Li)	0.0002	mg/L	-	-	0.00359	0.00414	0.00347	0.00354	0.00419	0.00561	0.00554	<0.00546	0.00378	0.00489	0.00387	<0.000050	0.00463	0.00515	0.00461	0.00539
Magnesium (Mg)	0.1	mg/L	-	-	8.45	7.97	8.15	8.36	9.27	9.12	8.34	8.44	9.25	9.27	9.13	0.211	9.22	8.20	8.42	9.48
Manganese (Mn)	0.0002	mg/L	-	-	<0.00020	0.00267	0.00296	0.00056	0.00027	0.00027	0.00023	<0.00020	0.0135	0.0513	0.0315	<0.000050	0.00144	0.0171	<0.00020	<0.00020
Mercury (Hg)	0.0005	ug/L	0.013	0.005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00449	<0.00050	<0.00050	<0.00050	<0.00050
Methylmercury (as MeHg)-Dissolved	0.0005	ug/L	0.002	0.001	<0.000050	0.000020	0.000037	0.000045	<0.000050	0.000043	0.000049	0.000032	<0.000050	<0.000020	<0.000020	<0.000020	<0.00005	0.000027	0.000053	0.000037
Molybdenum (Mo)	0.00005	mg/L	-	0.073	0.000129	0.000147	0.00014	0.000152	0.000157	0.000117	0.000135	0.000126	0.000135	0.000155	0.000133	0.0453	0.000148	0.000159	0.000125	0.000132
Nickel (Ni)	0.0002	mg/L	0.037 to 1.52[d]	0.004 to 0.170[d]	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00022	<0.00020	0.000148	<0.00020	<0.00020	<0.00020	0.00022
Phosphorus (P)	0.3	mg/L	-	-	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	0.0003	<0.30	<0.30	<0.30	<0.30
Potassium (K)	0.5	mg/L	-	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<0.30	<2.0	<2.0	<2.0	<2.0
Rhenium (Re)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Rubidium (Rb)	0.00002	mg/L	-	-	0.000674	0.000771	0.000551	0.000723	0.000741	0.000860	0.000909	0.000833	0.000849	0.00108	0.001	0.00101	0.000835	0.000839	0.000763	0.000851
Selenium (Se)	0.0002	mg/L	-	0.001[j]	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Silicon (Si)	0.05	mg/L	-	-	5.37	5.41	6.01	5.55	5.55	4.91	3.6	2.8	5.51	5.33	5.86	5.88	5.48	4.91	4.08	3.17
Silver (Ag)	0.000005	mg/L	-	0.00025	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Sodium (Na)	1	mg/L	-	-	<2.0	<2.0	<2.0	<2.0	2.8	4.7	5.3	4.3	2.5	2.4	2.4	2.6	3.2	4.1	4.2	4.3
Strontium (Sr)	0.00005	mg/L	-	-	0.0704	0.0788	0.0775	0.0702	0.0813	0.0950	0.0839	0.0813	0.083	0.0861	0.0865	0.0822	0.0833	0.0874	0.076	0.0796
Tellurium (Te)	0.00001	mg/L	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)	0.000002	mg/L	-	0.0008	<0.000010	<0.0000020	<0.0000020	<0.0000020	<0.0000040	<0.0000020	0.0000022	<0.0000020	<0.0000060	0.0000045	0.0000043	<0.0000050	<0.0000040	<0.0000020	<0.0000020	<0.0000020
Thorium (Th)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000119	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Tin (Sn)	0.0002	mg/L	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Titanium (Ti)	0.0002	mg/L	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00027	<0.00020	0.00022	<0.00020	<0.00020	<0.00020	<0.00020
Tungsten (W)	0.00001	mg/L	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000010	<0.000010	<0.000010
Uranium (U)	0.000002	mg/L	0.033	0.015	0.0000734	0.0000673	0.0000572	0.0000741	0.0000856	0.0000750	0.0000674	0.0000735	0.000334	0.000417	0.000432	0.000393	0.0000781	0.0000729	0.0000606	0.0000769
Vanadium (V)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000078	<0.000050	<0.000050	0.000076	<0.000050	<0.000050	<0.000050	<0.000050	0.000057	<0.000050
Yttrium (Y)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000760	<0.0000050	0.0000156	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Zinc (Zn)	0.001	mg/L	-	0.03	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0030	<0.0010	<0.0010	0.0013	0.0013
Zirconium (Zr)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
General Organics																				
Benzene	0.0005	mg/L	-	0.04	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Ethylbenzene	0.0005	mg/L	-	0.09	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050

Table A2.5 (Cont'd.)

Variables	Lowest Detection Limits	Units	Guideline AESRD[a] Acute	Chronic	IC-1 Winter	IC-1 Spring	IC-1 Summer	IC-1 Fall	OC-1 Winter	OC-1 Spring	OC-1 Summer	OC-1 Fall	OC-2 Winter	OC-2 Spring	OC-2 Summer	OC-2 Fall	PZ-1 Winter	PZ-1 Spring	PZ-1 Summer	PZ-1 Fall
F1(C6-C10)	0.1	mg/L	-	0.15	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F1-BTEX	0.1	mg/L	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F2 (>C10-C16)	0.1	mg/L	-	0.11	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
F3 (C16-C34)	0.25	mg/L	-	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
F4 (C34-C50)	0.25	mg/L	-	-	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Hydrocarbons, Recoverable (I.R.)	1	mg/L	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Oil & Grease-(IR)	1	mg/L			<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
m+p-Xylene	0.0005	mg/L	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Naphthenic Acids	1	mg/L	-	-	<1.0	<1.0	1.1	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0	<1.0	<1.0	<1.0	1
o-Xylene	0.0005	mg/L	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Total Phenols (4AAP)	0.001	mg/L	-	0.004	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	0.0005	mg/L	-	0.0005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Xylenes	0.00071	mg/L	-	0.03	<0.00071	<0.00071	<0.00050	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071	<0.00071
Major Ions																				
Bicarbonate (HCO3)	5	mg/L	-	-	193	182	196	183	205	187	136	145	216	205	201	204	205	184	142	146
Calcium (Ca)	0.05	mg/L	-	-	45.1	46.6	44.5		48.4	44.3	29		55.9	55.5	54.7		47.3	44.3	28.1	
Carbonate (CO3)	5	mg/L	-	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (Cl)	0.5	mg/L	640	120	<0.50	<0.50	<0.50	<0.50	<0.50	1.09	0.64	0.6	<5.0	1.21	1.15	1	<0.050	0.99	<0.50	0.58
Hydroxide (OH)	5	mg/L	-	-	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Ion Balance		%	-	-	80.8	98.7	89.5	98.7	82.4	96.6	97.5	94.4	85.7	96.9	98	94.4	80.3	94.6	90.8	98.7
Magnesium (Mg)	0.1	mg/L	-	-	8.63	8.24	8.8		9.45	8.56	9.26		9.31	9.27	9.43		9.12	8.56	8.82	
Potassium (K)	0.5	mg/L	-	-	0.81	0.9	0.58		0.95	1.1	0.85		1	0.98	0.89		1.01	1.1	0.78	
Sodium (Na)	1	mg/L	-	-	2	1.8	1.8		3.1	4.1	5.1		2.8	2.7	2.5		3.6	4.1	4.1	
Sulphate (SO4)	0.3	mg/L	-	128 to 429[e]	9.68	9.57	8.74	8.86	9.83	11.4	12.8	10.6	13.2	17.1	18.5	17.7	9.85	10.9	11.1	10.3
Sulphide (as S)	0.0015	mg/L	-	0.0019	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015
Nutrients and BOD																				
Ammonia (N)	0.05	mg/L	-	0.018 to 190[f]	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.05	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Biochemical Oxygen Demand	2	mg/L	-	-	<2.0	<2.0	3.8	<2.0	<2.0	<2.0	2.3	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.1	2.9	<2.0
Chlorophyll a	0.020	ug/L	-	-	0.096	<0.020	0.134	0.127	0.771	1.71	0.43	0.42	0.607	0.633	0.287	0.24	0.271	1.77	0.771	0.481
Nitrate (N)	0.02	mg/L	124	3	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.046	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.038	<0.020
Nitrate and Nitrite (N)	0.022	mg/L	-	-	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.046	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.038	<0.022
Nitrite (N)	0.01	mg/L	0.06-0.6[g]	0.02-0.2[g]	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Phosphorus (P)-Total	0.001	mg/L	-	varies[h]	0.0217	0.014	0.0086	0.0096	0.0095	0.0123	0.0077	0.0053	0.0089	0.0076	0.0032	0.005	0.0109	0.0272	0.0052	0.021
Phosphorus (P)-Total Dissolved	0.001	mg/L	-	varies[h]	0.0099	0.0108	0.0069	0.0114	0.0054	0.0137	0.0032	0.0046	0.0026	0.0023	0.0031	0.0018	0.0074	0.0164	0.0044	0.0168
Total Kjeldahl Nitrogen	0.2	mg/L	-	-	<0.20	<0.20	1.03	<0.20	<0.20	<0.20	0.46	<0.20	<0.20	<0.20	0.2	0.24	<0.20	<0.20	0.68	<0.20
Total Nitrogen		mg/L	-	varies[h]	0.222	0.222	1.052	0.222	0.222	0.222	0.506	0.222	0.222	0.222	0.222	0.262	0.222	0.222	0.718	0.222
Total Metals																				
Aluminum (Al)	0.003	mg/L	-	-	0.0101	0.0074	<0.0030	0.004	0.0131	0.0196	0.0035	0.0042	0.0579	0.0758	0.0073	0.0097	0.0066	0.0111	0.0044	0.0056
Antimony (Sb)	0.00003	mg/L	-	-	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030	<0.000030
Arsenic (As)	0.00005	mg/L	-	0.005	0.000095	0.000080	0.000058	0.000063	0.000115	0.000205	0.000216	0.000201	0.000172	0.000167	0.000112	0.000127	0.000175	0.000254	0.000208	0.0002
Barium (Ba)	0.0001	mg/L	-	-	0.0875	0.0827	0.0917	0.0791	0.0839	0.0754	0.0565	0.0577	0.106	0.116	0.115	0.111	0.091	0.0789	0.0654	0.0617
Beryllium (Be)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Bismuth (Bi)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron (B)	0.01	mg/L	29	1.5	0.015	0.019	0.016	0.014	0.023	0.045	0.035	0.033	0.019	0.025	0.019	0.021	0.027	0.036	0.034	0.031
Cadmium (Cd)	0.000005	mg/L	0.00011 to 0.0077[d]	0.00004 to 0.00037[d]	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Calcium (Ca)	0.05	mg/L	-	-	47.9	50.9	52.7	44	48	47.4	29.4	30.2	53.9	60.4	59.1	52.7	50.2	47.1	32.2	29.4
Cesium (Cs)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000134	0.0000165	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Chromium (Cr)	0.0005	mg/L	-	0.0089	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Cobalt (Co)	0.00005	mg/L		0.0013[i]	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000083	0.000063	<0.000050	<0.000050	<0.000050	0.000053	<0.000050	<0.000050
Copper (Cu)	0.0005	mg/L	0.0009 to 0.062[d]	0.007	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00059	<0.00050	<0.00050	0.00169
Gallium (Ga)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Iron (Fe)	0.03	mg/L	-	-	0.33	0.133	0.076	0.054	0.048	0.125	0.042	<0.030	0.318	0.226	0.17	0.211	0.049	0.177	<0.030	<0.030
Lead (Pb)	0.00005	mg/L	-	0.001 to 0.007[d]	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000065	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000064
Lithium (Li)	0.0004	mg/L	-	-	0.00392	0.00492	0.00361	0.00338	0.00473	0.00675	0.00538	0.00521	0.00422	0.00569	0.00404	0.00449	0.00525	0.00611	0.00458	0.00519
Total Metals (cont'd.)																				
Magnesium (Mg)	0.1	mg/L	-	-	8.61	7.97	8.11	8.28	9.83	8.36	8.82	8.24	9.74	9.01	8.22	10	10.1	8.31	8.1	8.22
Manganese (Mn)	0.0002	mg/L	-	-	0.0968	0.0368	0.018	0.0182	0.0119	0.0505	0.00394	0.00354	0.049	0.0416	0.0369	0.0453	0.0913	0.0926	0.00669	0.00382
Mercury (Hg)	0.0005	ug/L	0.013	0.005	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00053	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050

Table A2.5 (Cont'd.)

Variables	Lowest Detection Limits	Units	Guideline AESRD[a]		IC-1				OC-1				OC-2				PZ-1			
			Acute	Chronic	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Methyl Mercury	0.0005	ug/L	0.002	0.001	<0.000050	<0.000020	<0.000020	0.000062	<0.000050	0.000061	0.000061	0.000039	<0.000050	0.00002	<0.000020	<0.000020	0.000071	0.000061	0.000058	0.000038
Molybdenum (Mo)	0.00005	mg/L	-	0.073	0.000164	0.000158	0.000144	0.000152	0.000157	0.000125	0.000139	0.000131	0.000138	0.000158	0.000133	0.000148	0.000165	0.000188	0.000132	0.00014
Nickel (Ni)	0.0002	mg/L	0.037 to 1.52[d]	0.004 to 0.170[d]	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	0.00025	0.00022	0.00022	0.00029	0.00029	<0.00020	0.0003	0.00029	0.00031	0.00029	0.00049
Phosphorus (P)	0.3	mg/L	-	-	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.3	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)	2	mg/L	-	-	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Rhenium (Re)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Rubidium (Rb)	0.00002	mg/L	-	-	0.000738	0.000925	0.000546	0.000689	0.000853	0.00110	0.000882	0.000806	0.00105	0.00144	0.00098	0.00101	0.000943	0.00103	0.000787	0.000821
Selenium (Se)	0.0002	mg/L	-	0.001[i]	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Silicon (Si)	0.05	mg/L	-	-	5.59	6.04	5.87	5.83	5.95	5.27	3.79	2.93	5.91	6.28	5.45	5.88	5.82	5.11	3.87	2.92
Silver (Ag)	0.000005	mg/L	-	0.00025	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Sodium (Na)	2	mg/L	-	-	<2.0	2.2	<2.0	<2.0	2.8	5.2	4.9	4.1	2.5	2.9	2.5	2.6	3.4	4.4	4.1	4
Strontium (Sr)	0.0002	mg/L	-	-	0.0725	0.0634	0.0703	0.0659	0.0852	0.0811	0.0758	0.0742	0.0838	0.0801	0.0795	0.0822	0.09	0.0770	0.0753	0.0739
Tellurium (Te)	0.00001	mg/L	-	-	<0.000010	<0.000010	0.000016	<0.000010	<0.000010	<0.000010	0.000013	<0.000010	<0.000010	<0.000010	0.000012	<0.000010	<0.000010	<0.000010	0.000016	<0.000010
Thallium (Tl)	0.000005	mg/L	-	0.0008	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000051	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Thorium (Th)	0.000005	mg/L	-	-	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	0.0000177	0.000023	0.0000068	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Tin (Sn)	0.0002	mg/L	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Titanium (Ti)	0.0002	mg/L	-	-	<0.00020	<0.00020	<0.00020	<0.00020	0.00029	0.00051	<0.00020	<0.00020	0.00115	0.00179	<0.00020	0.00022	<0.00020	0.00028	<0.00020	<0.00020
Tungsten (W)	0.00001	mg/L	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000012	<0.000010	<0.000010
Uranium (U)	0.000002	mg/L	0.033	0.015	0.0000757	0.0000618	0.0000588	0.0000802	0.000081	0.0000685	0.0000722	0.0000675	0.000363	0.000423	0.000381	0.000393	0.0000808	0.0000672	0.0000651	0.0000675
Vanadium (V)	0.00005	mg/L	-	-	0.000057	<0.000050	<0.000050	<0.000050	0.000079	0.000098	0.000088	0.000051	0.000169	0.000226	<0.000050	<0.000050	<0.000050	0.000080	0.000076	0.000059
Yttrium (Y)	0.000005	mg/L	-	-	0.0000163	0.0000083	<0.0000050	<0.0000050	0.0000175	0.0000187	<0.0000050	<0.0000050	0.0000643	0.0000708	0.0000145	0.0000156	0.0000066	0.0000163	0.0000066	0.0000076
Zinc (Zn)	0.003	mg/L	-	0.03	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Zirconium (Zr)	0.00005	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000062	<0.000050	<0.000050	<0.000050	0.000069	<0.000050	<0.000050
Polycyclic Aromatic Hydrocarbons																				
1-Methylnaphthalene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.091	<0.020	<0.020	<0.020
2-Methylnaphthalene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.157	<0.020	<0.020	<0.020
Acenaphthene	0.02	ug/L	-	5.8	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Acenaphthylene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Acridine	4	ug/L	-	4.4	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Anthracene	0.012	ug/L	-	0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012
Benzo(a)anthracene	0.018	ug/L	-	0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018
Benzo(a)pyrene	0.005	ug/L	-	0.015	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0052	<0.0050	<0.0050	<0.0050
Benzo(b)fluoranthene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(g,h,i)perylene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Benzo(k)fluoranthene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Chrysene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Dibenzo(ah)anthracene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Fluoranthene	0.02	ug/L	-	0.04	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Fluorene	0.02	ug/L	-	3	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Indeno(1,2,3-cd)pyrene	0.02	ug/L	-	-	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Naphthalene	0.05	ug/L	-	1	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.342	<0.050	<0.050	<0.050
Phenanthrene	0.02	ug/L	-	0.4	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Pyrene	0.02	ug/L	-	0.025	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Quinoline	0.04	ug/L	-	3.4	<0.04	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040

- = not applicable

BOLD Indicates numbers exceeding guidelines

T = total metals, D = dissolved metals; all guideline values are for total fractions, except where specified.

a: Alberta Environment and Sustainable Resources Development (2014); most were adopted from CCME guidelines.

b: Dependent on background levels, see Environmental Quality guidelines for Alberta Surface Waters (2014) for more information. >25mg/L from background level.

c: For dissolved Al at pH>=6.5. At pH<6.5, acute guideline: e^([illegible])*1000; chronic guideline: e^([illegible])*1000

d: Hardness-dependant. Values given are at hardness levels ranging from 5 to 400 mg/L

e: Hardness-dependent Guideline = 128 mg/L at hardness 0-30 mg/L, 218 mg/L at hardness 31-75 mg/L, 309 at hardness 76-180 mg/L, 429 mg/L at hardness 181-250 mg/L

f: Guidelines for total ammonia are temperature and pH dependent; AESRD (2014) for additional information

g: Guidelines for nitrite are chloride dependent; see AESRD (2014) for additional information

h: Guidelines for total nitrogen and phosphorus are dependent on nature and conditions of ecosystems; see AESRD (2014) for additional information

i: Federal Environmental Quality Guideline. Varies with hardness.

j: displayed value is the Alert Concentration. Guideline Value is 0.002mg/L

Appendix A3

Sediment Quality Data

Table A3.1 Concentrations of sediment quality variables in the No Net Loss Lake, Fall 2018.

Analyte	Units	Guidelines				Station	
		ISQG[1]	PEL[2]	LEL[3]	CCME[4]	LZ	PZ
Physical properties							
% Clay	%	-	-	-	-	9.7	14.0
% Moisture	%	-	-	-	-	67.2	61.6
% Sand	%	-	-	-	-	44.7	41.0
% Silt	%	-	-	-	-	45.6	45.0
Texture	-	-	-	-	-	-	Loam
Inorganic and Organic Carbon							
Inorganic Carbon	%	-	-	-	-	4.60	0.52
Total Carbon by Combustion	%	-	-	-	-	9.06	8.28
Total Organic Carbon	%	-	-	-	-	4.46	7.76
Inorganic Carbon (as $CaCO_3$ Equivalent)	%	-	-	-	-	38.28	4.3
Hydrocarbons and Organic Compounds							
Benzene	mg/kg	-	-	-	-	<0.016	<0.017
Ethylbenzene	mg/kg	-	-	-	-	<0.049	<0.050
F1 (C6-C10)	mg/kg	-	-	-	30	<33	<33
F1-BTEX	mg/kg	-	-	-	-	<33	<33
F2 (C10-C16)	mg/kg	-	-	-	150	<25	34
F3 (C16-C34)	mg/kg	-	-	-	300	246	**644**
F4 (C34-C50)	mg/kg	-	-	-	2800	164	499
F4G-SG (GHH-Silica)	mg/kg	-	-	-	-	-	-
o-Xylene	mg/kg	-	-	-	-	<0.16	<0.17
Toluene	mg/kg	-	-	-	-	<0.046	<0.046
Total Hydrocarbons (C6-C50)	mg/kg	-	-	-	-	410	1180
Xylenes	mg/kg	-	-	-	-	<0.23	<0.23
m+p-Xylene	mg/kg	-	-	-	-	<0.16	<0.17
Polycyclic Aromatic Hydrocarbons							
2-Methylnaphthalene	mg/kg	0.0202	0.201	-	-	<0.014	<0.010
Acenaphthene	mg/kg	0.00671	0.0889	-	-	<0.054	<0.0050
Acenaphthylene	mg/kg	0.00587	0.128	-	-	<0.054	<0.0050
Anthracene	mg/kg	0.0469	0.245	-	-	<0.054	<0.0040
Benz(a)anthracene	mg/kg	0.0317	0.385	-	-	<0.014	<0.010
Benzo(a)pyrene	mg/kg	0.0319	0.782	-	-	<0.014	<0.010
Chrysene	mg/kg	0.0571	0.862	-	-	<0.014	0.015
Dibenz(a,h)anthracene	mg/kg	-	-	-	-	<0.0067	<0.0050
Fluoranthene	mg/kg	0.111	2.355	-	-	<0.014	<0.010

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

[1] Interim Sediment Quality Guideline (ISQG) (GoA 2018)

[2] Probable Effects Level (PEL) (GoA 2018)

[3] Lowest Effects Level (LEL) (GoA 2018)

[4] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

Table A3.1 (Cont'd.)

Analyte	Units	Guidelines				Station	
		ISQG[1]	PEL[2]	LEL[3]	CCME[4]	LZ	PZ
Fluorene	mg/kg	0.0212	0.144	-	-	<0.014	<0.010
Naphthalene	mg/kg	-	-	-	-	<0.014	<0.010
Phenanthrene	mg/kg	0.0419	0.515	-	-	<0.014	<0.010
Pyrene	mg/kg	0.053	0.875	-	-	<0.014	<0.010
Total Metals							
Aluminum (Al)	mg/kg	-	-	-	-	5850	8880
Antimony (Sb)	mg/kg	-	-	-	-	0.14	0.19
Arsenic (As)	mg/kg	5.9	17	-	-	2.5	4.56
Barium (Ba)	mg/kg	-	-	-	-	143	222
Beryllium (Be)	mg/kg	-	-	-	-	0.31	0.53
Bismuth (Bi)	mg/kg	-	-	-	-	<0.20	<0.20
Boron (B)	mg/kg	-	-	-	-	10.9	25.1
Cadmium (Cd)	mg/kg	0.6	3.5	-	-	0.077	0.148
Calcium (Ca)	mg/kg	-	-	-	-	111000	22900
Chromium (Cr)	mg/kg	37.3	90	-	-	13.2	15.2
Cobalt (Co)	mg/kg	-	-	-	-	4.19	6.83
Copper (Cu)	mg/kg	35.7	197	-	-	7.43	11.5
Iron (Fe)	mg/kg	-	-	-	-	12200	22500
Lead (Pb)	mg/kg	35	91.3	-	-	4.54	7.26
Lithium (Li)	mg/kg	-	-	-	-	6.8	11
Magnesium (Mg)	mg/kg	-	-	-	-	5310	4460
Manganese (Mn)	mg/kg	-	-	**460**	-	277	548
Mercury (Hg)	mg/kg	0.17	0.486	-	-	-	0.0301
Molybdenum (Mo)	mg/kg	-	-	-	-	0.4	0.56
Nickel (Ni)	mg/kg	-	-	**16**	-	12.3	17.8
Phosphorus (P)	mg/kg	-	-	-	-	391	539
Potassium (K)	mg/kg	-	-	-	-	1100	1370
Selenium (Se)	mg/kg	2	-	-	-	<0.20	0.43
Silver (Ag)	mg/kg	-	-	-	-	<0.10	<0.10
Sodium (Na)	mg/kg	-	-	-	-	88	136
Strontium (Sr)	mg/kg	-	-	-	-	99.3	84.1
Thallium (Tl)	mg/kg	-	-	-	-	0.09	0.156
Tin (Sn)	mg/kg	-	-	-	-	<2.0	<2.0
Titanium (Ti)	mg/kg	-	-	-	-	42.5	37.2
Uranium (U)	mg/kg	-	-	-	-	0.431	0.697
Vanadium (V)	mg/kg	-	-	-	-	17.8	25.6
Zinc (Zn)	mg/kg	123	315	-	-	26.2	43.1
Zirconium (Zr)	mg/kg	-	-	-	-	1.6	7.5

Values in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.

[1] Interim Sediment Quality Guideline (ISQG) (GoA 2018)

[2] Probable Effects Level (PEL) (GoA 2018)

[3] Lowest Effects Level (LEL) (GoA 2018)

[4] Guideline is for residential/parkland coarse (median grain size > 75 µm) surface soils (CCME 2008).

Appendix A4

Macrophyte Communities

Table A4.1 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ1).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.23	Cypress like sedge	*Carex pseudocyperus*	20
0	0.23	Water Sedge	*Carex aquatilis*	10
0	0.23	Narrow leaved pondweed	*Potamogeton pusillus*	25
0	0.23	Coontail	*Ceratophyllum demersum*	5
1	0.50	Coontail	*Ceratophyllum demersum*	60
1	0.50	White Water-buttercup	*Ranunculus circinatus*	10
2	0.68	Coontail	*Ceratophyllum demersum*	80
2	0.68	Narrow leaved pondweed	*Potamogeton pusillus*	10
3	1.07	Coontail	*Ceratophyllum demersum*	90
3	1.07	White Water-buttercup	*Ranunculus circinatus*	10
4	1.07	Coontail	*Ceratophyllum demersum*	100
5	-	Coontail	*Ceratophyllum demersum*	100
6	-	Coontail	*Ceratophyllum demersum*	100
7	-	Coontail	*Ceratophyllum demersum*	100
8	2	Coontail	*Ceratophyllum demersum*	100

Table A4.21 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ2).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.20	Marsh Cinquefoil	*Comarum palustre*	5
0	0.20	Northern Watermillfoil	*Myriophyllum exalbescens*	5
0	0.20	Rush sp.	*Juncus sp.*	3
1	0.27	Coontail	*Ceratophyllum demersum*	3
2	0.40	Coontail	*Ceratophyllum demersum*	10
3	0.50	Coontail	*Ceratophyllum demersum*	5
4	0.66	Coontail	*Ceratophyllum demersum*	5
5	0.91	Coontail	*Ceratophyllum demersum*	5
5	0.91	Northern Watermillfoil	*Myriophyllum exalbescens*	5
6	0.98	-	-	-
7	1.15	Coontail	*Ceratophyllum demersum*	60
7	1.15	Northern Watermillfoil	*Myriophyllum exalbescens*	5
8 to 15	1.15 to 3	Coontail	*Ceratophyllum demersum*	80
8 to 15	1.15 to 3	Narrow leaf pondweed	*Potamogeton pusillus*	10
8 to 15	1.15 to 3	Northern Watermillfoil	*Myriophyllum exalbescens*	10

Table A4.3 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ3).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.34	Water Sedge	*Carex aquatilis*	10
0	0.34	Cypress like sedge	*Carex pseudocyperus*	5
0	0.34	Water bur-reed	*Sparganium fluctuans*	2
0	0.34	Coontail	*Ceratophyllum demersum*	10
0	0.34	Sandbar willow	*Salix exigua*	2
1	0.3	Coontail	*Ceratophyllum demersum*	2
1	0.3	Algae sp.	-	2
2	0.5	Coontail	*Ceratophyllum demersum*	5
3	0.68	Coontail	*Ceratophyllum demersum*	1
4	0.73	-	-	-
5	0.97	-	-	-
6	1.25	Coontail	*Ceratophyllum demersum*	10
7	1.25	Coontail	*Ceratophyllum demersum*	100
8	-	Coontail	*Ceratophyllum demersum*	100
9	-	Coontail	*Ceratophyllum demersum*	100
10	-	Coontail	*Ceratophyllum demersum*	100
11	-	Coontail	*Ceratophyllum demersum*	100
12	-	Coontail	*Ceratophyllum demersum*	100
13	-	Coontail	*Ceratophyllum demersum*	100
14	-	Coontail	*Ceratophyllum demersum*	100
15	-	Coontail	*Ceratophyllum demersum*	100
16	-	Coontail	*Ceratophyllum demersum*	100
17	-	Coontail	*Ceratophyllum demersum*	100
18	-	Coontail	*Ceratophyllum demersum*	100
19	-	Coontail	*Ceratophyllum demersum*	100
20	-	Coontail	*Ceratophyllum demersum*	100
21	-	Coontail	*Ceratophyllum demersum*	100
22	-	Coontail	*Ceratophyllum demersum*	100
23	-	Coontail	*Ceratophyllum demersum*	100
24	-	Coontail	*Ceratophyllum demersum*	100
25	-	Coontail	*Ceratophyllum demersum*	100
26	-	Coontail	*Ceratophyllum demersum*	100
27	-	Coontail	*Ceratophyllum demersum*	100
28	-	Coontail	*Ceratophyllum demersum*	100

Table A4.4 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ4).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.25	Water Sedge	*Carex aquatilis*	20
0	0.25	Cypress like sedge	*Carex pseudocyperus*	20
0	0.25	Willow sp.	*Salix sp.*	1
0	0.25	Alder sp.	*Alnus sp.*	1
1	0.34	Algae sp.	-	5
2	0.42	Coontail	*Ceratophyllum demersum*	2
3	0.54	Coontail	*Ceratophyllum demersum*	5
4	0.76	Coontail	*Ceratophyllum demersum*	5
5	0.85	Coontail	*Ceratophyllum demersum*	5
6	1	Coontail	*Ceratophyllum demersum*	10
7	1.16	Coontail	*Ceratophyllum demersum*	90
8	1.16	Coontail	*Ceratophyllum demersum*	100
9	-	Coontail	*Ceratophyllum demersum*	100
10	-	Coontail	*Ceratophyllum demersum*	100
11	-	Coontail	*Ceratophyllum demersum*	100
12	-	Coontail	*Ceratophyllum demersum*	100
13	-	Coontail	*Ceratophyllum demersum*	100
14	3	Coontail	*Ceratophyllum demersum*	100

Table A4.5 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ5).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.26	Water sedge	*Carex aquatilis*	5
0	0.26	Cypress like sedge	*Carex pseudocyperus*	5
0	0.26	Willow sp.	*Salix sp.*	1
0	0.26	Cattail	*Typha latifolia*	1
0	0.26	White Waterbuttercup	*Ranunculus circinatus*	1
1	0.31	White Waterbuttercup	*Ranunculus circinatus*	1
1	0.31	Cattail	*Typha latifolia*	1
2	0.48	White Waterbuttercup	*Ranunculus circinatus*	5
3	0.57	-	-	-
4	0.7	Coontail	*Ceratophyllum demersum*	5
5	0.82	Coontail	*Ceratophyllum demersum*	10
6	1	Coontail	*Ceratophyllum demersum*	30
7	1.2	Coontail	*Ceratophyllum demersum*	90
7	1.2	White Waterbuttercup	*Ranunculus circinatus*	10
8 to 22	1.2 to 3	Coontail	*Ceratophyllum demersum*	90
8 to 22	1.2 to 3	Narrow leaved pondweed	*Potamogeton pusillus*	10

Table A4.6 Percent cover of macrophyte species in the littoral zone of No Net Loss Lake, Fort Hills Oil Sands Project, July 18, 2018 (Transect LZ6).

Transect Station at Plot Centre (m)	Depth (m)	Common Name	Botanical Name	Percent Cover
0	0.28	Water Sedge	*Carex aquatilis*	10
0	0.28	Cyppress Like Sedge	*Carex pseudocyperus*	10
0	0.28	Turned sedge	*Carex retrorsa*	5
0	0.28	Willow sp.	*Salix sp.*	3
0	0.28	White Waterbuttercup	*Ranunculus circinatus*	2
0	0.28	Coontail	*Ceratophyllum demersum*	50
0	0.28	Ribbon-leafed pondweed	*Potamogen epihydus*	2
1	0.5	Ribbon-leafed pondweed	*Potamogen epihydus*	5
1	0.5	Water Sedge	*Carex aquatilis*	5
1	0.5	Burreed	*Sparganium fluctuans*	5
1	0.5	Coontail	*Ceratophyllum demersum*	60
2	0.8	White Waterbuttercup	*Ranunculus circinatus*	5
2	0.8	Coontail	*Ceratophyllum demersum*	40
3	1.04	Coontail	*Ceratophyllum demersum*	40
4	1.15	Coontail	*Ceratophyllum demersum*	40
5	1.15	Coontail	*Ceratophyllum demersum*	35
6	-	Coontail	*Ceratophyllum demersum*	35
7	-	Coontail	*Ceratophyllum demersum*	35
8	-	Coontail	*Ceratophyllum demersum*	35
9	-	Coontail	*Ceratophyllum demersum*	35
10	-	Coontail	*Ceratophyllum demersum*	35
11	-	Coontail	*Ceratophyllum demersum*	35
12	-	Coontail	*Ceratophyllum demersum*	35
13	3	Coontail	*Ceratophyllum demersum*	35

Appendix A5

Fish and Fish Habitat Data

Table A5.1 Lake chub lacustrine habitat suitability model for NNLL.

Variable		Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S, CS, Bd	-	-
V2	cover	R, C, Bo, vegetation, woody debris, submergent and emergent plants	-	-	-	-
V3	depth (m)	≤ 2	>2 to 5	-	> 5	-
V4	% littoral cover	>20 to 50	>10 to 20; >50 to 65	>5 to 10; >65 to 75	0 to 5; >75 to 100	-
V5	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	<1	-	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI	0.50
Limiting Variable	Littoral Cover

Table A5.2 Lake chub lake suitability ratings per habitat variable.

Variable		Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.10	-	0.90	-	-
V2	cover	1.00	-	-	-	-
V3	depth	0.29	0.44	-	0.27	-
V4	% littoral cover	-	-	1.00	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V6	pH	1.00	-	-	-	-

Table A5.3 Lake chub lake weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.10	-	0.45	-	-	0.55
V2	cover	1.00	-	-	-	-	1.00
V3	depth	0.29	0.33	-	0.07	-	0.69
V4	% littoral cover	-	-	0.50	-	-	0.50
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.4 Burbot lacustrine habitat suitability model for the NNLL - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S	CS	detritus
V2	late winter dissolved oxygen (mg/L) [b]	≥ 7	≥ 5 to < 7	≥ 2 to < 5	≥ 1 to < 2	< 1
V3	summer average maximum temperature [C]	< 12	≥ 12 to < 15	> 15 to 18	> 18	-
V4	% littoral cover	>30 to 50	>20 to 30; >50 to 65	>10 to 20; >65 to 75	>0 to 10; >75 to 100	0
V5	depth (m)	> 0 to 2	-	≥ 2 to 3	> 3 to 5	> 5

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

[C] Average summer temperature is average water temperature in July and August.

HSI (Rearing)	0.25
Limiting Variable	Summer Average Max Temp

Table A5.5 Burbot lacustrine suitability ratings per habitat variable - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.10	-	0.44	0.56	-
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V3	summer average maximum temperature	-	-	-	1.00	-
V4	% littoral cover	-	-	1.00	-	-
V5	depth (m)	0.29	-	0.11	0.33	0.27

Table A5.6 Burbot lacustrine weighted-average suitability rating per habitat variable - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.10	-	0.22	0.14	-	0.46
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V3	summer average maximum temperature	-	-	-	0.25	-	0.25
V4	% littoral cover	-	-	0.50	-	-	0.50
V5	depth (m)	0.29	-	0.06	0.08	0.00	0.43

Table A5.7 Burbot lacustrine habitat suitability model for the NNLL – Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S	CS	detritus
V2	late winter dissolved oxygen (mg/L) [b]	≥ 7	≥ 5 to < 7	≥ 2 to < 5	≥ 1 to < 2	< 1
V3	summer average maximum temperature [C]	< 12	≥ 12 to < 15	> 15 to 18	> 18	-

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

[C] Average summer temperature is average water temperature in July and August.

HSI (Feeding)	0.25
Limiting Variable	Summer Average Max Temp

Table A5.8 Burbot lacustrine suitability ratings per habitat variable – Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.10	-	0.44	0.56	-
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V3	summer average maximum temperature	-	-	-	1.00	-

Table A5.9 Burbot lacustrine weighted-average suitability rating per habitat variable – Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.10	-	0.33	0.14	-	0.57
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V3	summer average maximum temperature	-	-	-	0.25	-	0.25

Table A5.10 Burbot lacustrine habitat suitability model for the NNLL – Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S	CS	detritus
V2	late winter dissolved oxygen (mg/L) [b]	≥ 7	≥ 5 to < 7	≥ 2 to < 5	≥ 1 to < 2	< 1
V3	Depth	≥ 1 to < 3	> 3 to 5	> 5 to 7	> 7 to 10	> 10 or < 1

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI (Spawning)	0.46
Limiting Variable	Substrate

Table A5.11 Burbot lacustrine suitability ratings per habitat variable – Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.10	-	0.44	0.56	-
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V3	Depth	0.24	0.33	0.27	-	0.16

Table A5.12 Burbot lacustrine weighted-average suitability rating per habitat variable – Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.10	-	0.22	0.14	-	0.46
V2	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V3	Depth	0.24	0.25	0.14	-	0.00	0.63

Table A5.13 White sucker lacustrine habitat suitability model for the NNLL.

V1	Maximum monthly average turbidity during the year (JTU). *[Assume that turbidity is not limiting and assign SI = 1.0]*	1.00	
V2	Weekly average pH during the year under stable conditions. *[Establish background levels using available regional data or base on site-specific monitoring; if data are not available, assume not limiting and assign SI = 1.0]*	0.90	8.47 = Average annual pH
V3	Minimum dissolved oxygen levels (mg/L) during May through August in areas of most suitable water temperature. *[Assume not limiting and assign SI = 1.]*	1.00	
V4	Average of mean weekly water temperatures (°C) during July and August (for adults and juveniles).	1.00	20.09 degrees = average temperature during July and August
V5	Average of mean weekly water temperatures (°C) during July and August (for fry)	0.50	Assumes spawning in outlet channel, see HSI model for the outlet channel. (14.05 degrees = average temperature in the outlet channel in July and August)
V6	Average of mean weekly water temperatures (°C) during spawning and incubation (April through July)	1.00	Assumes spawning in outlet channel, see HSI model for the outlet channel. (13.37 degrees = average temperature in the outlet channel April through July)
V11	Littoral spawning substrate. *[The SI criteria were revised from the published model. For boulder, cobble and gravel, SI = 1; for sand, SI = 0.5; for clay/silt or bedrock, SI = 0.05.]*	1.00	Assumes spawning in outlet channel, see HSI model for the outlet channel.
	C_{wq} = MIN(V1, V2, V3, V4)	0.90	
	C_R = [MIN(V3, V5, V6, V11) * MIN(V5, V6, V7, V8)]$^{1/2}$	0.50	Assumes spawning in outlet channel, see HSI model for the outlet channel.
	HSI = (C_{WQ}*C_R)$^{1/2}$	**0.67**	Limiting Variable = Average of mean weekly water temperatures during July and August (for fry)

Table A5.14 Northern pike lacustrine habitat suitability model for the NNLL.

HSI Values for V1 to V9 based on Inskip (1982)			
V1	Ratio of spawning habitat area to summer habitat area. *[This ratio was determined based on the estimated proportion of the area that would be less than 1 m deep during spring and with aquatic vegetation or debris.]*	0.75	Quotient = 0.16, use SI Curve B (Inskip 1982)
V2	Drop in water level (m) during embryo and fry stages. *[i.e., during the period from spawning through to the end of June]*	0.80	Drops approximately 16.3 cm between May and June
V3	Percent of midsummer area with emergent or submergent aquatic vegetation	1.00	Approximately 68% midsummer area with emergent or submergent vegetation.
V4	Log_{10} of total dissolved solids concentration in surface waters during midsummer	1.00	2.18 (From July 2018 PZ1 WQ results)
V5	Least suitable pH in spawning habitat during embryo and fry stages	1.00	pH never goes outside of preferred range (6 to 9)
V6	Average length of frost-free season (days)	1.00	157 days
V7	Maximal weekly average temperature (°C) of surface waters. *[Using the warmest week (7 days) of the year, take the average of the daily peak temperatures during that period.]*	1.00	22.54 degrees (This is the average of the max temps over the hotest week in summer)
V10	Late winter dissolved oxygen (DO). *If DO is greater than 2 mg/L, SI = 1; if DO is less than2 mg/L, SI = 0.5. Late winter DO criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, ther may exist some local areas where late winter DO is greater than the measured concentrations.*	1.00	
	HSI is smallest of above variables	**0.75**	
	Limiting Variable	**Ratio of Spawning Habitat to Summer Habitat**	

Table A5.15 Yellow perch lacustrine habitat suitability model for the NNLL

Use HSI documents – Golder (2008) and Kreiger et al. (1983) for specific HSI graphs.			
V1	Percent littoral area during summer.	0.70	40% area < or equal to 3 m depth.
V3	Percent cover during summer within littoral areas	0.60	Approx 68% cover in areas less than 3 m deep
V4	Most suitable water temperature within the water column during midsummer (adult, juvenile and fry).	1.00	Used WQ profile from July - 21.7 degrees
V5	Most suitable water temperature within littoral areas during spawning and embryo development. *[Take several measurements throughout the lake and average them.]*	1.00	11.35 - Based on average of WQ measurements at 6 LZ sites in May
V6	Minimum dissolved oxygen level at the two locations selected for the most suitable temperature for variables V4 and V5.	1.00	Values above 5 mg/L will occur at more than one location in the water column at any given time of the year
V7	Degree-days (between 4 and 10°C) from October 30 to April 1 [*Not relevant in the region; assign SI = 1.0*]	1.00	
V8	pH range during the year. *[As yellow perch have high acidity tolerance, assume not limiting and assign SI=1.0]*	1.00	
V9	Trophic status of lake or lake section.	1.00	mesotrophic
V10	*Late winter DO. Should be measured at the deepest location in the lake. If DO is greater than or equal to 3 mg/L, SI=1; if DO is >1 and < 3 mg/L, SI=0.5; if DO is < 1 mg/L, SI=0.*	1.00	Values above 3 mg/L will occur at more than one location in the water column at any given time of the year
	HSI	**0.60**	
	Limiting Variable	**Percent cover during summer within littoral areas.**	

As noted for the riverine model, variable V7 should be excluded from the analysis by assigning a SI value of 1.0 in all cases. Graphs for determining the SIs for each of the remaining variables (except V10) are included in Krieger et al. (1983). The HSI is set at the minimum SI value for habitat variables V1 and V3 to V10.

Table A5.16 Longnose sucker lacustrine habitat suitability model for the NNLL.

Use HSI documents – Golder (2008) and Edwards (1983) for specific HSI graphs.			
V1	Spawning location. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	Under the assumption that suitable spawning habitat occurs in the inlet and outlet channels.
V2	Depth of riffle for spawning. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1.0. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	Under the assumption that suitable spawning habitat occurs in the inlet and outlet channels.
V3	Current velocity within spawning habitat. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1.0. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	Under the assumption that suitable spawning habitat occurs in the inlet and outlet channels.
V4	Mean water temperature during spawing and incubation.	1.00	10.5 degrees, profile averaged in May
V5	Percent riffles in spawning streams. *[V5 was removed from the model]*	NA	
V6	Substrate type. *[This is part of the embryo component of the model and represents substrate in spawning areas. In areas where the HSI value would be less than 0.5 due to this variable, but there is potential use other than spawning, assign SI = 0.5]*	1.00	Under the assumption that suitable spawning substrate occurs in inlet and out let channels.
V7	Percent cover in the form of vegetation, boulders or rubble in shallow edge or shoreline areas (May-July). [*To be applied within the littoral zone in late summer. SI graph was modified as described and indicated in the figure (Golder 2008 page 42). SI=1.0 for the range from 15 to 75 % cover within the littoral zone.*]	1.00	Approximately 68% cover in littoral zone.
V8	Fluctuation in water level in mid-summer (reservoirs).	0.95	0.1 m (Difference between max and min in July)
V9	Maximum depth. *[The SI graph was modified as described and indicated in the figure (Golder 2008 page 42). At 3 m, SI=0; at 10m, SI=1; from 10 m to 100m, published graph was followed]*	0.60	max depth of 6.9 m taken from bathymetric map.
V10	Average turbidity (Secchi disk) during the growing season. *[Assumed to be not limiting; assign SI=1.0]*	1.00	
V11	pH range during the summer.	1.00	8.66 (profile averaged for July and August)
V12	Dissolved oxygen during the summer. *[To interpreted as the average mid-day dissolved oxygen concentration within the epilimnion during July and August.]*	1.00	11.4 mg/L based on average DO taken at 1.0 m depth in July and August
V13	Mean water temperature during the summer. [*To be interpreted as the mean water temperature within the epilimnion during July and August. The SI graph was modified as described and indicated in the figure (Golder 2008 Page 43. For the temperature range from 12 to 20 °C, SI=1; use published graph for temperatures from 0 to 12 °C; use linear trend from SI=1 at 20 to SI = 0 at 28°C.*]	1.00	20.5 °C (based on average temp taken at 1.0 m depth in July and August).
C_E	embryo stage = $(V1*V2*V3*V4^2*V6)^{1/6}$	1.00	
C_F	fry stage= (V7+V8)/2	0.98	
C_{J-A}	juvenile - adult stage= (V9+V10+V11+V12+2V13)/6	0.77	
	If V13 is $\leq$ 0.7, C_{J-A} equals the lowest of V13 or the above equations		
HSI	$HSI=(C_E^2 * C_F * C_{J-A})^{1/4}$	0.93	
	HSI	**0.93**	
	Limiting Variable	**Maximum Depth**	

Table A5.17 Pearl dace lacustrine habitat suitability model for the NNLL.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S, CS	-	R, C	Bo, Bd	-
V2	cover	submergent and emergent vegetation	-	R, C	Bo, Bd	-
V3	depth (m)	≤ 2	-	>2 to 5	> 5	-
V4	% littoral cover	>20 to 50	>10 to 20; >50 to 65	>5 to 10; >65 to 75	0 to 5; >75 to 100	-
V5	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	-	<1	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI	0.50
Limiting Variable	% littoral cover

Table A5.18 Pearl dace lacustrine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.90	-	0.10	-	-
V2	cover	0.68	-	0.096	-	-
V3	depth (m)	0.29	-	0.44	0.27	-
V4	% littoral cover	-	-	1	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V6	pH	1.00	-	-	-	-

Table A5.19 Pearl dace lacustrine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.90	-	0.05	-	-	0.95
V2	cover	0.68	-	0.05	-	-	0.73
V3	depth (m)	0.29	-	0.22	0.07	-	0.58
V4	% littoral cover	-	-	0.5	-	-	0.50
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.20 Brook stickleback lacustrine habitat suitability model for the NNLL.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S and CS	-	-	Bo, Bd, C, R	-
V2	nesting materials	algae, submergent plants	emergent plants	inundated vegetation	other, eg., woody debris	none
V3	depth (m)	≤ 2	-	> 2 to 5	>5	-
V4	% littoral zone cover	>50	>30 to 50	>20 to 30	>0 to 20	0
V5	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	-	<1	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	**0.58**
Limiting Variable	**Depth**

Table A5.21 Brook stickleback lacustrine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.90	-	-	0.096	-
V2	nesting materials	0.67	0.02	0.00	0.000	-
V3	depth	0.29	-	0.44	0.27	-
V4	% littoral zone cover	1.0	-	-	-	-
V5	late winter dissolved oxygen (mg/L)	1.0	-	-	-	-
V6	pH	1.0	-	-	-	-

Table A5.22 Brook stickleback lacustrine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.90	-	-	0.024	-	0.93
V2	nesting materials	0.67	0.01	0.001	0.0	-	0.68
V3	depth	0.29	-	0.22	0.07	-	0.58
V4	% littoral zone cover	1.00	-	-	-	-	1.00
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.23 Fathead minnow lacustrine habitat suitability model for the NNLL.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S, CS	-	Bo, C, R	Bd	-
V2	cover	submergent and emergent plants	-	other, e.g., woody debris, rock	-	-
V3	spawning material	rocks, logs, debris, broadleaf veg.	-	emergent plants	-	-
V4	depth	≤ 2	-	>2 to 5	>5	-
V5	% littoral zone cover	>50	>30 to 50	>20 to 30	>0 to 20	0
V6	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	-	<1	-
V7	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	0.58
Limiting Variable	Depth

Table A5.24 Fathead minnow lacustrine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.90	-	0.10	-	-
V2	cover	0.68	-	0.00	-	-
V3	spawning material	1.00	-	-	-	-
V4	depth	0.29	-	0.44	0.27	-
V5	% littoral cover	1.00	-	-	-	-
V6	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V7	pH	1.00	-	-	-	-

Table A5.25 Fathead minnow lacustrine weighted-average suitability rating per habitat variable

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.90	-	0.05	-	-	0.95
V2	cover	0.68	-	0.00	-	-	0.68
V3	spawning material	1.00	-	-	-	-	1.00
V3	depth	0.29	-	0.22	0.07	-	0.58
V5	% littoral cover	1.00	-	-	-	-	1.00
V6	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V7	pH	1.00	-	-	-	-	1.00

Table A5.26 Slimy Sculpin lacustrine habitat suitability model for the NNLL.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, R, C, G, logs	-	-	S, CS	-
V2	% cover as suitable substrate i.e., R, C, Bo, Woody Debris	>30	>20 to 30	>10 to 20	>0 to 10	0
V3	depth	≤ 2	>2 to 5	>5	-	-
V4	late winter dissolved oxygen (mg/L) [b]	≥ 2	-	<2	-	-

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	0.25
Limiting Variable	% cover as suitable substrate

Table A5.27 Slimy sculpin lacustrine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.10	-	-	0.90	-
V2	% cover as suitable substrate i.e., R, C, Bo, Woody Debris	-	-	-	1.00	-
V3	depth	0.29	0.44	0.27	-	-
V4	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-

Table A5.28 Slimy sculpin lacustrine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.10	-	-	0.22590553	-	0.32
V2	% cover as suitable substrate	-	-	-	0.25	-	0.25
V3	depth	0.29	0.33	0.14	-	-	0.75
V4	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00

Table A5.29 Lake chub riverine habitat suitability model for NNLL outlet channel.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S, CS, Bd	-	-
V2	instream cover	R, C, Bo, vegetation, woody debris, submergent and emergent plants	-	-	-	-
V3	channel unit	runs, flats pools	-	riffles	-	rapids
V4	% instream cover	>20 to 50	>10 to 20; >50 to 65	>5 to 10 >65 to 75	0 to 5; >75 to 100	-
V5	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	<1	-	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI	0.80
Limiting Variable	Channel unit

Table A5.30 Lake chub riverine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.76	-	0.24	-	-
V2	instream cover	1.00	-	-	-	-
V3	channel unit	0.60	-	0.40	-	-
V4	% instream cover	1.00	-	-	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V6	pH	1.00	-	-	-	-

Table A5.31 Lake chub riverine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.76	-	0.12	-	-	0.88
V2	instream cover	1.00	-	-	-	-	1.00
V3	channel unit	0.60	-	0.20	-	-	0.80
V4	% instream cover	1.00			-	-	1.00
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.32 Burbot riverine habitat suitability model for the NNLL outlet channel - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S	CS	detritus
V2	channel unit	snye, pools, bacwater areas	flats	runs	riffles	chutes, falls
V3	late winter dissolved oxygen (mg/L) [b]	$\geq$ 6	-	$\geq$ 2 to < 6	-	< 2
V4	summer average maximum temperature [C]	< 12	$\geq$ 12 to < 15	> 15 to 18	> 18	-
V5	% instream cover	>30 to 50	>20 to 30; >50 to 65	>10 to 20; >65 to 75	>0 to 10; >75 to 100	0

(a) Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

(b) Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

(C) Average summer temperature is average water temperature in July and August.

HSI (Rearing)	0.41
Limiting Variable	Channel Unit

Table A5.33 Burbot riverine suitability ratings per habitat variable - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.76	-	-	0.24	-
V2	channel unit	0.03	-	0.57	0.40	-
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V4	summer average maximum temperature	-	1.00	-	-	-
V5	% instream cover	1.00	-	-	-	-

Table A5.34 Burbot riverine weighted-average suitability rating per habitat variable - Rearing.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.76	-	-	0.06	-	0.82
V2	channel unit	0.03	-	0.28	0.10	-	0.41
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V4	summer average maximum temperature	-	0.75	-	-	-	0.75
V5	% instream cover	1.00	-	-	-	-	1.00

Table A5.35 Burbot riverine habitat suitability model for the NNLL - Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, C, R, G	-	S	CS	detritus
V2	channel unit	snye, pools, bacwater areas	flats, runs	riffles	-	chutes, falls
V3	late winter dissolved oxygen (mg/L) [b]	≥ 7	≥ 5 to < 7	≥ 2 to < 5	≥ 1 to < 2	< 1
V4	summer average maximum temperature [C]	< 12	≥ 12 to < 15	> 15 to 18	> 18	-
V5	% instream cover	>30 to 50	>20 to 30; >50 to 65	>10 to 20; >65 to 75	>0 to 10; >75 to 100	0

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

[C] Average summer temperature is average water temperature in July and August.

HSI (Feeding)	0.66
Limiting Variable	Channel Unit

Table A5.36 Burbot riverine suitability ratings per habitat variable - Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.76	-	-	0.24	-
V2	channel unit	0.03	0.57	0.40	-	-
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V4	summer average maximum temperature	-	1.00	-	-	-
V5	% instream cover	1.00	-	-	-	-

Table A5.37 Burbot riverine weighted-average suitability rating per habitat variable - Feeding.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.76	-	-	0.06	-	0.82
V2	channel unit	0.03	0.43	0.20	-	-	0.66
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V4	summer average maximum temperature	-	0.75	-	-	-	0.75
V5	% instream cover	1.00	-	-	-	-	1.00

Table A5.38 Burbot riverine habitat suitability model for the NNLL - Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S, CS	-	Bo, R, C	-	Bd, detritus
V2	channel unit	snye, pools, bacwater areas	flats	runs	riffles	chutes, falls
V3	late winter dissolved oxygen (mg/L) [b]	≥ 6	-	≥ 2 to < 6	-	< 2

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI (Spawning)	0.41
Limiting Variable	Channel Unit

Table A5.39 Burbot riverine suitability ratings per habitat variable - Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.62	-	0.38	-	-
V2	channel unit	0.03	-	0.57	0.40	-
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-

Table A5.40 Burbot riverine weighted-average suitability rating per habitat variable - Spawning.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.62	-	0.19	-	-	0.81
V2	channel unit	0.03	-	0.28	0.10	-	0.41
V3	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00

Table A5.41 White sucker riverine habitat suitability model for the NNLL outlet channel.

Use HSI documents - Golder (2008) and Twomey et al. (1984) for specific HSI graphs.			
V1	Maximum monthly average turbidity during the year (JTU). [*Assume that turbidity is not limiting and assign SI = 1.0*]	1.00	
V2	Weekly average pH during the year under stable conditions. [*Establish background levels using available regional data or base on site-specific monitoring; if data are not available, assume not limiting and assign SI = 1.0*]	0.90	8.44 = Average annual pH
V3	Minimum dissolved oxygen levels (mg/L) during May through August in areas of most suitable water temperature [*Assume not limiting and assign SI = 1.*]	1.00	
V4	Average of mean weekly water temperatures (°C) during July and August (for adults and juveniles).	0.70	12.1 degrees = average temperature during July and August
V5	Average of mean weekly water temperatures (°C) during July and August (for fry)	0.35	12.1 degrees = average temperature during July and August
V6	Average of mean weekly water temperatures (°C) during spawning and incubation (April through July)	0.90	11.6 degrees = average temperature during May through July
V7	Average riffle velocity (cm/s) during spawning and incubation [*If any riffles with suitable spawning substrates are present, assign SI = 1; if no riffles with suitable spawning substrates are present assign SI = 0.5*]	1.00	
V8	Average riffle depth (cm) during spawning and incubation. [*If any riffles with suitable spawning substrates are present, assign SI = 1; if no riffles with suitable spawning substrates are present assign SI = 0.5*]	1.00	
V9	Percent instream and overhanging shoreline cover	1.00	55% (42 % instream cover for fish (61-150 mm), 13% overhead cover)
V10	Percent pools during average summer flows	0.10	3 % average across OC-2 and Oc-3 HUs
	C_{wq} = MIN(V1, V2, V3, V4)	0.70	
	C_R = MIN(V5, V6, V7, V8)	0.35	Assumes spawning in outlet channel, see HSI model for the outlet channel.
	C_C = (V9 + V10)/2	0.55	
	HSI = $(C_{WQ}*C_R*C_C)^{1/3}$	**0.51**	
	Limiting Variable	**Percent pools during summer flow**	

Table A5.42 Northern pike riverine habitat suitability model for the NNLL.

HSI Values for V1 to V9 based on Inskip (1982)			
V1	Ratio of spawning habitat area to summer habitat area *[This ratio was determined based on the estimated proportion of the area that would be less than 1 m deep during spring and with aquatic vegetation or debris.]*	0.50	Quotient = 0.35, use SI Curve C (Inskip 1982)
V2	Drop in water level (m) during embryo and fry stages. *[i.e., during the period from spawning through to the end of June]*	0.89	Drops approximately 13.4 cm in May and June based on logger data
V3	Percent of midsummer area with emergent or submergent aquatic vegetation	1.00	approximately 50.4 % aquatic veg in mid-summer area
V4	Log_{10} of total dissolved solids concentration in surface waters during midsummer	1.00	2.28 (From July 2018 TDS samples)
V5	Least suitable pH in spawning habitat during embryo and fry stages	1.00	pH never goes outside of preferred range (6 to 9)
V6	Average length of frost-free season (days)	1.00	157 days
V7	Maximal weekly average temperature (°C) of surface waters. *[Using the warmest week (7 days) of the year, take the average of the daily peak temperatures during that period.]*	0.90	16.4 degrees (This is the average of the max temps over the hotest week in summer)
V8	Area of backwaters, pools or standing water (<5 cm/s) during summer, as a percent of the total surface area. [The habitats with velocities less than 5 cm/s will be assumed to include 100% of the areas of all backwaters, pools, flats and impoundments plus 20% of the area of runs (to represent low-velocity stream margins within run habitats). If insufficient data are available, assign SI = 1.0]	0.30	27% of area with velocities less than 5 cm/s (16% habitat <5 cm/s, plus 20% of run habitat)
V9	Stream gradient (m/km). [Assume reaches with gradients >5 m/km have no habitat suitable for northern pike.]	0.00	5.6 m per km
V10	Late winter dissolved oxygen (DO). *If DO is greater than 2 mg/L, SI = 1; if DO is less than2 mg/L, SI = 0.5. Late winter DO criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, ther may exist some local areas where late winter DO is greater than the measured concentrations.*	1.00	
	HSI is smallest of above variables	**0**	
	Limiting Variable	**stream gradient**	

Table A5.43 Yellow perch riverine habitat suitability model for the NNLL outlet channel.

Use HSI documents - Golder (2008) and Kreiger et al. (1983) for specific HSI graphs.			
V2	Percent pool and backwater areas during average summer flow.	0.75	16% of area with velocities less than 5 cm/s (3% pool habitat plus 13% of run habitat)
V3	Percent cover during summer within pools and backwater areas.	0.90	Approximately 35% overhead cover in the form of brush or woody debris as described by Krieger et al. 1983.
V4	Most suitable water temperature within the water column during midsummer (adult, juvenile and fry).	0.20	12.1°C is the average for July and August
V5	Most suitable water temperature within pools and backwaters during spawning and embryo development.	1.00	9.9°C average of May water temperature.
V6	Minimum dissolved oxygen level at the two locations selected for the most suitable temperature for variables V4 and V5.	1.00	Values above 5 mg/L will occur at more than one location in the water column at any given time of the year
V7	Degree-days (between 4 and 10°C) from October 30 to April 1 [*Not relevant in the region; assign SI = 1.0*]	1.00	
V8	pH range during the year. *[As yellow perch have high acidity tolerance, assume not limiting and assign SI=1.0]*	1.00	
	HSI	**0.20**	
	Limiting Variable	**Most suitable water temperature during midsummer**	

As noted for the riverine model, variable V7 should be excluded from the analysis by assigning a SI value of 1.0 in all cases. Graphs for determining the SIs for each of the remaining variables (except V10) are included in Krieger et al. (1983). The HSI is set at the minimum SI value for habitat variables V1 and V3 to V10.

Table A5.44 Longnose sucker riverine habitat suitability model for the NNLL.

Use HSI documents - Golder (2008) and Edwards (1983) for specific HSI graphs.			
V1	Spawning location. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	
V2	Depth of riffle for spawning. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1.0. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	
V3	Current velocity within spawning habitat. *[If any riffle areas are present and substrate is suitable for spawning, assign SI = 1.0. If any riffle areas are present and there is no suitable substrate for spawning (e.g., bedrock or rubble), assign SI = 0.5. If no riffle areas are present, assign SI = 0.5]*	1.00	
V4	Mean water temperature during spawing and incubation.	1.00	9.9°C Average of May water temperature.
V5	Percent riffles in spawning streams. *[V5 was removed from the model]*	NA	
V6	Substrate type. *[This is part of the embryo component of the model and represents substrate in spawning areas. In areas where the HSI value would be less than 0.5 due to this variable, but there is potential use other than spawning, assign SI = 0.5]*	1.00	Gravel and cobble occurs in spawning areas.
V7	Percent cover in the form of vegetation, boulders or rubble in shallow edge or shoreline areas (May-July). [*SI graph was modified as described and indicated in the figures on Page 39 (Golder 2008). For streams with mean channel width up to 10 m, SI = 1 for the range from 15 to 75% cover for the entire stream width. For streams greater than 10 m in channel width, SI = 1 for the range from 10 to 75 % cover. This midification was required because the field measurement of percent cover was based on entire stream width. Average widths are based on a weighted average of width data that includes ponded areas.*]	1.00	
V11	pH range during the summer.	1.00	8.2 = average pH for July and August
V12	Dissolved oxygen during the summer.	1.00	11.2 mg/L = average DO in July and August
V13	Mean water temperature during the summer. [*The mean water temperature during July and August. The SI graph was modified as described and indicated in the figure (Golder 2008 Page 39). For the temperature range from 12 to 20 °C, SI=1; use published graph for temperatures from 0 to 12 °C; use linear trend from SI=1 at 20 to SI = 0 at 28°C.]*	1.00	12.1 degrees = average temperature during July and August
V14	Channel units. For pools and runs, SI = 1, for riffles, SI = 0.75; for flats, SI = 0.5; for rapids, SI = 0.25	1.00	pools and runs present
C_E	embryo stage = $(V1{*}V2{*}V3{*}V4^2{*}V6)^{1/6}$	1.00	
C_F	fry stage= V7	1.00	
$C_{J\text{-}A}$	juvenile - adult stage= (V11+V12+2V13+V14)/5	1.00	
	If V13 is $\leq$ 0.7, $C_{J\text{-}A}$ equals the lowest of V13 or the above equations		
HSI	$HSI=(C_E^2 {*} C_F {*} C_{J\text{-}A})^{1/4}$	1.00	
	HSI	**1.00**	
	Limiting Variable	**None**	

Table A5.45 Pearl dace riverine habitat suitability model for the NNLL outlet channel.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S, CS	-	R, C	Bo, Bd	-
V2	instream cover	vegetation, woody debris, submergent and emergent plants	-	R, C	Bo, Bd	-
V3	channel unit	pools, runs, flats	-	riffles	-	rapids
V4	% instream cover	>20 to 50	>10 to 20; >50 to 65	>5 to 10; >65 to 75	0 to 5; >75 to 100	-
V5	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	<1	-	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners.

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations.

HSI	0.55
Limiting Variable	Instream Cover

Table A5.46 Pearl dace riverine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.62	-	0.32	0.06	-
V2	instream cover	0.51	-	0.08	0.02	-
V3	channel unit	0.60	-	0.40	-	-
V4	% instream cover	1.00	-	-	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V6	pH	1.00	-	-	-	-

Table A5.47 Pearl dace riverine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.62	-	0.16	0.01	-	0.80
V2	instream cover	0.51	-	0.04	0.01	-	0.55
V3	channel unit	0.60	-	0.20	-	-	0.80
V4	% instream cover	1.00	-	-	-	-	1.00
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.48 Brookstickleback riverine habitat suitability model for the NNLL outlet channel.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S and CS	-	-	Bo, Bd, C, R	-
V2	nesting materials	algae, submergent plants	emergent plants	inundated vegetation	other, eg., woody debris	none
V3	channel unit	flats, pools, backwater areas	-	runs	riffles	rapids, chutes, falls
V4	% instream cover	>50	>30 to 50	>20 to 30	>0 to 20	0
V5	late winter dissolved oxygen (mg/L) [b]	$\geq$ 1	-	-	<1	-
V6	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	0.41
Limiting Variable	Channel Unit

Table A5.49 Brook stickleback riverine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.62	-	-	0.38	-
V2	nesting materials	0.51	-	-	-	-
V3	channel unit	0.03	-	0.57	0.40	-
V4	% instream cover	1.00	-	-	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V6	pH	1.00	-	-	-	-

Table A5.50 Brook stickleback riverine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.62	-	-	0.09	-	0.72
V2	nesting materials	0.51	-	-	-	-	0.51
V3	channel unit	0.03	-	0.28	0.10	-	0.41
V4	% instream cover	1.00	-	-	-	-	1.00
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V6	pH	1.00	-	-	-	-	1.00

Table A5.51 Fathead minnow riverine habitat suitability model for the NNLL outlet channel.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	G, S, CS	-	Bo, C, R	Bd	-
V2	instream cover	submergent and emergent plants	-	other, e.g., woody debris, rock	-	-
V3	spawning material	underside of rocks, logs, debris, broadleaf veg.	-	verticle surfaces of emergent plants	-	no suitable material
V4	channel unit	flats, pools, backwater areas	runs	-	riffles	rapids, chutes, falls
V5	% instream cover	>50	>30 to 50	>20 to 30	>0 to 20	0
V6	late winter dissolved oxygen (mg/L) [b]	≥ 1	-	<1	-	-
V7	pH	6 to 9	-	5.5 to <6	-	<5.5 or >9

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	0.73
Limiting Variable	Instream Cover

Table A5.52 Fathead minnow riverine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.62	-	0.38	-	-
V2	instream cover	0.51	-	0.40	-	-
V3	spawning material	1.00	-	-	-	-
V4	channel unit	0.03	0.57	-	0.40	-
V5	% instream cover	1.00	-	-	-	-
V6	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-
V7	pH	1.00	-	-	-	-

Table A5.53 Fathead minnow riverine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.62	-	0.19	-	-	0.81
V2	instream cover	0.51	-	0.20	-	-	0.70
V3	spawning material	1.00	-	-	-	-	1.00
V3	channel unit	0.03	0.43	-	0.10	-	0.56
V5	% instream cover	1.00		-	-	-	1.00
V6	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00
V7	pH	1.00	-	-	-	-	1.00

Table A5.54 Slimy Sculpin riverine habitat suitability model for the NNLL outlet channel.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate [a]	Bo, R, C, G, logs	-	-	S, CS	-
V2	instream cover	R, C, Bo, woody debris	-	vegetation	-	absence of in situ cover
V3	channel unit	runs, riffles, rapids	-	-	flats, pools	-
V4	% instream cover as suitable substrate (i.e., %R, C, Bo, woody debris)	>30	> 20 to 30	>10 to 20	> 0 to 10	0
V5	late winter dissolved oxygen (mg/L) [b]	≥ 2	-	<2	-	-

[a] Bd = bedrock, Bo = boulder (>256 mm), C cobble (>64 to 256 mm, rounded), R = rubble (>64 to 256 mm, angular), G = gravel (>2 to 64 mm), S = sand (>0.06 to 2.0 mm) and CS = clay / silt (<= 0.06 mm) includes detritus (Bradbury et al. 1999). The distinction between cobble and rubble is that cobble material has a smooth rounded shape while rubble is material in the same size range, but with sharp angular corners

[b] Late winter dissolved oxygen (DO) criteria are based on the assumptions that if measured late winter DO is greater than the indicated concentration, DO is not limiting at any time of year, and if measured late winter DO is less than the indicated concentration, DO may be limiting in winter but not during the open-water period. In addition, since DO is not measured in all areas within a watercourse or waterbody, there may exist some local areas where late winter DO is greater than the measured concentrations

HSI	0.65
Limiting Variable	Instream Cover

Table A5.55 Slimy sculpin riverine suitability ratings per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)
V1	substrate	0.76	-	-	0.24	-
V2	instream cover	0.40	-	0.51	-	-
V3	channel unit	0.97	-	-	0.03	-
V4	% instream cover as suitable substrate (i.e., %R, C, Bo, woody debris)	1.00	-	-	-	-
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-

Table A5.56 Slimy sculpin riverine weighted-average suitability rating per habitat variable.

	Variable	Excellent (SI = 1.0)	Above Average (SI = 0.75)	Average (SI = 0.5)	Below Average (SI = 0.25)	None (SI = 0.0)	SI value
V1	substrate	0.76	-	-	0.06	-	0.82
V2	instream cover	0.40	-	0.25	-	-	0.65
V3	channel unit	0.97	-	-	0.01	-	0.98
V4	% instream cover as suitable substrate (i.e., %R, C, Bo, woody debris)	1.00	-	-	-	-	1.00
V5	late winter dissolved oxygen (mg/L)	1.00	-	-	-	-	1.00

Table A5.57 Fish habitat data collected from the inlet and outlet channel of the No Net Loss Lake, Fall 2018.

Site ID	Habitat Unit	Habitat Type	DS UTM E	DS UTM N	US UTM E	US UTM N	Velocity m/s				Site Length (m)	Max Depth (m)	Channel Width (m) Average	Wetted Width (m) Average	Unstable Banks %	Instream Cover for Fish (%)			Overhead Cover for Fish (%)			Substrate Fractions (%)							
							25%	50%	75%	Average						0-60 mm	61-150 mm	>150 mm	0-60 mm	61-150 mm	>150 mm	Organics	Clay/Silt	Sand	Gravel	Cobble	Boulder	Bedrock	Veg
IC-1	HU1	RF	468470	6375112	468517	6375074	0.64	0.51	0.58	0.58	67	0.42	3.20	1.45	10	90	60	30	75	60	40	2.5	2.5	20	55	15	5	0	5
OC-2	HU1	R3	468128	6374253	468140	6374271	0.03	0.04	0.045	0.04	24.1	0.45	5.68	1.91	0	90	60	10	15	15	5	0	15	0	40	35	10	0	85
OC-2	HU2	RF	468140	6374271	468149	6374264	0.035	0.055	0.11	0.07	11	0.19	4.70	1.38	0	90	60	0	5	5	0	0	5	0	20	75	0	0	45
OC-2	HU3	P3	468149	6374264	468154	6374270	0.01	0.02	0.03	0.02	7.5	0.43	6.50	2.15	0	90	60	20	0	0	0	0	5	0	80	5	10	0	85
OC-2	HU4	R3	468154	6374270	468160	6374275	0.01	0.09	0.05	0.05	13	0.25	5.90	1.88	0	60	50	10	5	5	0	0	5	0	40	45	10	0	35
OC-2	HU5	RF	468160	6374225	468182	6374275	0.035	0.175	0.02	0.08	39	0.22	5.80	1.50	0	80	80	50	30	30	20	0	5	0	40	50	5	0	70
OC-2	HU6	R3	468182	6374275	468188	6374275	0.01	0.02	0.04	0.02	7.7	0.26	4.90	2.10	0	80	60	30	40	30	20	0	20	0	60	10	10	0	85
OC-2	HU7	RF	468788	6374275	468189	6374282	0.11	0.21	0.11	0.14	7.4	0.13	5.80	1.05	0	60	40	10	40	30	10	0	10	0	65	25	0	0	-
OC-3	HU1	R3	467904	6374066	467947	6374091	0.52	0.35	0.2	0.36	67.3	0.52	7.50	4.30	0	75	40	10	5	2.5	0	0	55	20	10	10	5	0	20
OC-3	HU2	RF	467947	6374091	467958	6374102	0.37	0.18	0.32	0.29	27.1	0.4	4.45	1.40	0	40	20	5	Trace	0	0	0	5	5	40	45	5	0	10
OC-3	HU3	R3	467958	6374102	467964	6374131	0.14	0.21	0.14	0.16	38.1	0.5	4.50	1.40	0	60	30	5	0	0	0	0	60	20	5	10	5	0	40
OC-3	HU4	RF	467964	6374131	467975	6374141	0.60	0.59	0.31	0.50	-	0.28	8.80	1.95	0	40	20	5	Trace	0	0	0	25	10	20	40	5	0	20

Table A5.57 cont'd

Site ID	Habitat Unit	Water Depth (M)				In Situ WQ				Instream Cover Components (%)					Overhead Cover Components (%)				Comments
		25%	50%	75%	Average	DO mg/L	Con (us/cm)	pH	Temp	Aquatic Veg	Woody Debris	Subs	Depth/ Turbulence	Turbidity	Undercut Banks	Shrubs/ Trees	Woody Debris	Grasses	
IC-1	HU1	0.11	0.08	0.06	0.08	12.11	310.6	7.96	4.953	0	50	30	20	0	10	50	40	0	Some undercut banks, lots of woody debris
OC-2	HU1	0.12	0.14	0.12	0.13	11.68	291.4	7.99	8.745	85	0	10	5	0	0	80	0	20	Shallow, slow moving
OC-2	HU2	0.12	0.16	0.14	0.14	11.56	291	7.98	9.17	30	0	60	10	0	0	50	0	50	
OC-2	HU3	0.14	0.2	0.13	0.16	11.5	291	7.95	9.44	40	0	30	30	0	0	0	0	0	
OC-2	HU4	0.08	0.11	0.11	0.10	11.31	289.2	7.96	9.42	70	0	30	0	0	0	90	0	10	
OC-2	HU5	0.1	0.14	0.1	0.11	11.15	288.9	7.89	9.377	40	0	50	10	0	0	10	0	90	
OC-2	HU6	0.14	0.22	0.16	0.17	11.07	280.9	7.96	9.567	65	0	30	5	0	0	0	0	100	
OC-2	HU7	0.06	0.08	0.07	0.07	11.2	279.5	7.96	9.625	50	0	40	10	0	0	30	0	70	
OC-3	HU1	0.13	0.15	0.21	0.16	12.08	362.7	8.15	6.153	75	5	15	5	0	0	40	50	10	
OC-3	HU2	0.16	0.27	0.18	0.20	12.1	362.7	8.12	5.751	40	0	45	15	0	0	0	0	100	
OC-3	HU3	0.25	0.33	0.22	0.27	12.04	362.2	8.06	5.653	55	0	40	5	0	0	5	0	95	
OC-3	HU4	0.16	0.18	0.14	0.16	11.98	362.1	8.03	5.578	5	0	85	10	0	0	0	0	0	

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	-	39	NRPK	310	202.20	989001001534439	3 (1R)	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	-	40	NRPK	241	95.80	989001001534396	3 (2R)	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	322	-	YLPR	70	3.93	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	323	-	YLPR	104	15.67	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	324	-	YLPR	110	17.52	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	325	-	YLPR	121	24.20	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	326	-	YLPR	115	20.28	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	327	-	YLPR	124	23.25	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	328	-	YLPR	68	3.92	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	329	-	YLPR	63	3.34	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	330	-	YLPR	60	3.11	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	331	-	YLPR	72	5.18	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	332	-	SPSH	66	3.56	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	333	-	SPSH	16	0.05	-	-	-	-	-	500
Island Per.	Boat EF	1	16/Aug/18	14:02	16/Aug/18	14:23	334	-	SPSH	20	0.14	-	-	-	-	-	500
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	29	NRPK	273	147.50	989001001534397	3 (2R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	30	NRPK	305	199.20	989001001534420	4 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	31	NRPK	291	203.10	989001001554421	3 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	32	NRPK	272	153.60	989001001534443	3 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	33	NRPK	229	91.70	989001001534417	3 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	34	NRPK	252	99.30	989001001534444	3 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	35	NRPK	227	74.90	989001001534442	2 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	-	36	NRPK	249	106.80	989001001534357	3 (1R)	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	214	-	YLPR	122	22.60	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	215	-	YLPR	133	30.70	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	216	-	YLPR	130	31.40	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	217	-	YLPR	75	5.20	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	218	-	YLPR	107	14.60	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	219	-	YLPR	134	31.30	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	220	-	YLPR	114	17.90	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	221	-	YLPR	113	17.70	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	222	-	YLPR	135	32.80	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	223	-	YLPR	110	16.20	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	224	-	YLPR	72	4.50	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	225	-	NRPK	96	7.40	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	226	-	YLPR	60	6.60	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	227	-	SPSH	33	0.50	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	228	-	SPSH	40	0.86	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	229	-	SPSH	26	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	230	-	SPSH	26	0.21	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	231	-	SPSH	26	0.15	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	232	-	SPSH	32	0.44	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	233	-	SPSH	21	0.12	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	234	-	SPSH	25	0.16	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	235	-	SPSH	16	0.06	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	236	-	SPSH	27	0.18	-	-	-	-	-	2298

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	237	-	SPSH	25	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	238	-	SPSH	24	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	239	-	SPSH	26	0.21	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	240	-	SPSH	22	0.17	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	241	-	SPSH	23	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	242	-	SPSH	25	0.22	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	243	-	SPSH	25	0.15	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	244	-	SPSH	26	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	245	-	SPSH	34	0.38	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	246	-	SPSH	26	0.17	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	247	-	SPSH	23	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	248	-	SPSH	27	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	249	-	SPSH	39	0.50	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	250	-	SPSH	33	0.36	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	251	-	SPSH	31	0.37	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	252	-	SPSH	29	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	253	-	SPSH	28	0.20	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	254	-	SPSH	43	0.74	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	255	-	SPSH	27	0.16	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	256	-	SPSH	19	0.17	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	257	-	SPSH	34	0.36	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	258	-	SPSH	25	0.11	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	259	-	SPSH	25	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	260	-	SPSH	28	0.20	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	261	-	SPSH	35	0.44	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	262	-	SPSH	25	0.16	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	263	-	SPSH	30	0.37	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	264	-	SPSH	26	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	265	-	SPSH	25	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	267	-	SPSH	21	0.12	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	268	-	SPSH	31	0.28	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	269	-	SPSH	25	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	270	-	SPSH	30	0.36	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	271	-	SPSH	25	0.15	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	272	-	SPSH	23	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	273	-	SPSH	22	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	274	-	SPSH	30	0.33	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	275	-	SPSH	21	0.12	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	276	-	SPSH	26	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	277	-	SPSH	22	0.10	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	278	-	SPSH	40	0.72	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	279	-	SPSH	20	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	280	-	SPSH	24	0.17	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	281	-	SPSH	31	0.33	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	282	-	SPSH	25	0.15	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	283	-	SPSH	27	0.21	-	-	-	-	-	2298

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	284	-	SPSH	30	0.29	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	285	-	SPSH	25	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	286	-	SPSH	22	0.15	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	287	-	SPSH	20	0.22	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	288	-	SPSH	34	0.32	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	289	-	SPSH	32	0.28	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	290	-	SPSH	30	0.33	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	291	-	SPSH	30	0.36	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	292	-	SPSH	25	0.11	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	293	-	SPSH	25	0.16	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	294	-	SPSH	25	0.18	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	295	-	SPSH	21	0.11	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	296	-	SPSH	27	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	297	-	SPSH	27	0.21	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	298	-	SPSH	18	0.06	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	300	-	SPSH	20	0.09	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	301	-	SPSH	30	0.35	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	302	-	SPSH	23	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	303	-	SPSH	25	0.11	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	304	-	SPSH	26	0.20	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	305	-	SPSH	35	0.50	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	306	-	SPSH	22	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	307	-	SPSH	24	0.14	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	308	-	SPSH	20	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	309	-	SPSH	18	0.09	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	310	-	SPSH	25	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	311	-	SPSH	20	0.10	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	312	-	SPSH	18	0.19	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	313	-	SPSH	26	0.17	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	314	-	SPSH	22	0.13	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	315	-	SPSH	33	0.55	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	316	-	SPSH	30	0.44	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	317	-	SPSH	38	0.66	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	318	-	SPSH	27	0.23	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	319	-	SPSH	32	0.38	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	320	-	SPSH	17	0.04	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	321	-	SPSH	16	0.02	-	-	-	-	-	2298
Lake Per.	Boat EF	1	16/Aug/18	10:00	16/Aug/18	13:30	241(b)	-	SPSH	21	0.18	-	-	-	-	-	2298
LZ1	Boat EF	1	16/Aug/18	15:14	16/Aug/18	15:20	-	-	NFC	-	-	-	-	-	-	-	128
LZ1	Hoop Net	1	14/Aug/18	11:33:00 AM	15/Aug/18	8:35:00 AM	-	12	NRPK	257	195.04	989001001534346	4 (1R)	21.03	-	-	-
LZ1	Hoop Net	2	15/Aug/18	08:35	16/Aug/18	08:15	-	-	NFC	-	-	-	-	23.67	-	-	-
LZ1	Minnow Trap	1	13/Aug/18	12:33:00 PM	14/Aug/18	7:29:00 AM	-	-	NFC	-	-	-	-	18.93	-	-	-
LZ1	Minnow Trap	2	13/Aug/18	12:33:00 PM	14/Aug/18	07:29	-	-	NFC	-	-	-	-	18.93	-	-	-
LZ1	Minnow Trap	3	13/Aug/18	12:33:00 PM	14/Aug/18	07:29	-	-	NFC	-	-	-	-	18.93	-	-	-
LZ1	Minnow Trap	4	13/Aug/18	12:33:00 PM	14/Aug/18	07:29	-	-	NFC	-	-	-	-	18.93	-	-	-
LZ1	Minnow Trap	5	13/Aug/18	12:33:00 PM	14/Aug/18	07:29	-	-	NFC	-	-	-	-	18.93	-	-	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ1	Minnow Trap	6	14/Aug/18	8:55:00 AM	15/Aug/18	07:30	-	-	NFC	-	-	-	-	22.58	-	-	-
LZ1	Minnow Trap	7	14/Aug/18	8:55:00 AM	15/Aug/18	07:30	-	-	NFC	-	-	-	-	22.58	-	-	-
LZ1	Minnow Trap	8	14/Aug/18	08:55	15/Aug/18	07:30	-	-	NFC	-	-	-	-	22.58	-	-	-
LZ1	Minnow Trap	9	14/Aug/18	8:55:00 AM	15/Aug/18	07:30	-	-	NFC	-	-	-	-	22.58	-	-	-
LZ1	Minnow Trap	10	14/Aug/18	08:55	15/Aug/18	07:30	-	-	NFC	-	-	-	-	22.58	-	-	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	95	-	SPSH	36	0.35	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	96	-	SPSH	35	0.42	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	97	-	SPSH	26	0.16	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	98	-	SPSH	36	0.55	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	99	-	SPSH	43	0.80	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	100	-	SPSH	30	0.25	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	101	-	SPSH	36	0.58	-	-	-	-	1.0	-
LZ1	Seine Net	1	15/Aug/18	10:00	15/Aug/18	10:35	102	-	SPSH	74	4.69	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	103	-	SPSH	34	0.38	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	104	-	SPSH	41	0.57	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	105	-	SPSH	30	0.27	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	106	-	SPSH	24	0.16	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	107	-	SPSH	41	0.86	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	108	-	SPSH	28	0.23	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	109	-	SPSH	24	0.18	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	110	-	SPSH	36	0.38	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	111	-	SPSH	29	0.34	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	112	-	SPSH	35	0.46	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	113	-	SPSH	34	0.41	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	114	-	SPSH	36	0.34	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	115	-	SPSH	36	0.28	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	116	-	SPSH	33	0.39	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	117	-	SPSH	37	0.52	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	118	-	SPSH	46	0.85	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	119	-	SPSH	81	6.62	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	120	-	SPSH	47	1.16	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	121	-	SPSH	36	0.42	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	122	-	SPSH	30	0.54	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	123	-	SPSH	35	0.45	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	124	-	SPSH	42	0.79	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	125	-	SPSH	45	0.95	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	126	-	SPSH	39	0.61	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	127	-	SPSH	35	0.45	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	128	-	SPSH	45	0.74	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	129	-	SPSH	38	0.58	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	130	-	SPSH	35	0.31	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	131	-	SPSH	30	0.33	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	132	-	SPSH	36	0.61	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	133	-	SPSH	64	0.35	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	134	-	SPSH	80	5.41	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	135	-	SPSH	32	0.35	-	-	-	-	1.0	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	136	-	SPSH	30	0.26	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	137	-	SPSH	29	0.18	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	138	-	SPSH	33	0.36	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	139	-	SPSH	40	0.62	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	140	-	SPSH	36	0.50	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	141	-	SPSH	41	0.80	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	142	-	SPSH	76	5.01	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	143	-	SPSH	78	6.01	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	144	-	SPSH	83	7.03	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	145	-	NRPK	101	6.95	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	146	-	NRPK	93	4.61	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	147	-	YLPR	68	3.73	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	148	-	YLPR	56	2.16	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	149	-	EMSH	65	2.20	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	150	-	EMSH	70	2.84	-	-	-	-	1.0	-
LZ1	Seine Net	2	15/Aug/18	10:36	15/Aug/18	11:05	151	-	EMSH	65	2.46	-	-	-	-	1.0	-
LZ1	Seine Net	3	15/Aug/18	11:06	15/Aug/18	11:15	-	16	NRPK	247	108.00	989001001534400	3 (1R)	-	-	1.0	-
LZ2	Boat EF	1	16/Aug/18	15:30	16/Aug/18	15:36	-	41	BRBT	361	234.00	989001001534363	ua	-	-	-	124
LZ2	Boat EF	1	16/Aug/18	15:30	16/Aug/18	15:36	335	-	YLPR	111	20.20	-	-	-	-	-	124
LZ2	Boat EF	1	16/Aug/18	15:30	16/Aug/18	15:36	336	-	YLPR	122	24.80	-	-	-	-	-	124
LZ2	Boat EF	1	16/Aug/18	15:30	16/Aug/18	15:36	337	-	YLPR	121	18.50	-	-	-	-	-	124
LZ2	Boat EF	1	16/Aug/18	15:30	16/Aug/18	15:36	338	-	YLPR	115	21.70	-	-	-	-	-	124
LZ2	Hoop Net	1	13/Aug/18	2:15:00 PM	14/Aug/18	10:15	-	3	NRPK	173	38.50	989001001534424	2 (0R)	20.00	-	-	-
LZ2	Minnow Trap	1	13/Aug/18	11:57:00 AM	14/Aug/18	07:35	-	-	NFC	-	-	-	-	19.63	-	-	-
LZ2	Minnow Trap	2	13/Aug/18	11:57	14/Aug/18	7:35:00 AM	-	-	NFC	-	-	-	-	19.63	-	-	-
LZ2	Minnow Trap	3	13/Aug/18	11:57	14/Aug/18	07:35	-	-	NFC	-	-	-	-	19.63	-	-	-
LZ2	Minnow Trap	4	13/Aug/18	11:57	14/Aug/18	7:35:00 AM	-	-	NFC	-	-	-	-	19.63	-	-	-
LZ2	Minnow Trap	5	13/Aug/18	11:57	14/Aug/18	07:35	-	-	NFC	-	-	-	-	19.63	-	-	-
LZ2	Minnow Trap	6	14/Aug/18	9:05:00 AM	15/Aug/18	7:34:00 AM	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ2	Minnow Trap	7	14/Aug/18	9:05:00 AM	15/Aug/18	07:34	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ2	Minnow Trap	8	14/Aug/18	09:05	15/Aug/18	07:34	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ2	Minnow Trap	9	14/Aug/18	09:05	15/Aug/18	07:34	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ2	Minnow Trap	10	14/Aug/18	09:05	15/Aug/18	07:34	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ2	Seine Net	1	15/Aug/18	14:30	15/Aug/18	14:37	-	20	NRPK	306	169.30	989001001534373	2(4R)	-	-	1.0	-
LZ2	Seine Net	1	15/Aug/18	14:30	15/Aug/18	14:37	154	-	SPSH	30	0.24	-	-	-	-	1.0	-
LZ2	Seine Net	2	15/Aug/18	14:38	15/Aug/18	14:47	-	-	NFC	-	-	-	-	-	-	1.0	-
LZ2	Seine Net	3	15/Aug/18	14:48	15/Aug/18	14:55	-	-	NFC	-	-	-	-	-	-	1.0	-
LZ3	Boat EF	1	16/Aug/18	15:38	16/Aug/18	15:44	-	-	NFC	-	-	-	-	-	-	-	124
LZ3	Hoop Net	1	14/Aug/18	11:55:00 AM	15/Aug/18	8:52:00 AM	-	13	NRPK	440	554.60	989001001534456	5 (2R)	20.95	-	-	-
LZ3	Hoop Net	1	14/Aug/18	11:55:00 AM	15/Aug/18	8:52:00 AM	-	14	NRPK	269	110.46	989001001534318	3 (1R)	20.95	-	-	-
LZ3	Hoop Net	2	15/Aug/18	8:52:00 AM	16/Aug/18	12:00:00 AM	-	28	NRPK	350	172.00	989001001534361	4 (1R)	23.50	-	-	-
LZ3	Hoop Net	2	15/Aug/18	8:52:00 AM	16/Aug/18	8:22:00 AM	213	-	YLPR	125	24.80	-	-	23.50	-	-	-
LZ3	Minnow Trap	1	13/Aug/18	11:48	14/Aug/18	7:41:00 AM	-	-	NFC	-	-	-	-	19.88	-	-	-
LZ3	Minnow Trap	2	13/Aug/18	11:48:00 AM	14/Aug/18	7:41:00 AM	-	-	NFC	-	-	-	-	19.88	-	-	-
LZ3	Minnow Trap	3	13/Aug/18	11:48	14/Aug/18	7:41:00 AM	-	-	NFC	-	-	-	-	19.88	-	-	-
LZ3	Minnow Trap	4	13/Aug/18	11:48	14/Aug/18	7:41:00 AM	-	-	NFC	-	-	-	-	19.88	-	-	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ3	Minnow Trap	5	13/Aug/18	11:48:00 AM	14/Aug/18	07:41	-	-	NFC	-	-	-	-	19.88	-	-	-
LZ3	Minnow Trap	6	14/Aug/18	09:13	15/Aug/18	7:42:00 AM	93	-	NRPK	93	4.74	-	-	22.48	-	-	-
LZ3	Minnow Trap	7	14/Aug/18	09:13	15/Aug/18	07:42	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ3	Minnow Trap	8	14/Aug/18	09:13	15/Aug/18	07:42	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ3	Minnow Trap	9	14/Aug/18	9:13:00 AM	15/Aug/18	7:42:00 AM	94	-	NRPK	100	6.35	-	-	22.48	-	-	-
LZ3	Minnow Trap	10	14/Aug/18	09:13	15/Aug/18	7:42:00 AM	-	-	NFC	-	-	-	-	22.48	-	-	-
LZ3	Seine Net	1	15/Aug/18	12:45	15/Aug/18	12:55	-	17	NRPK	305	181.20	989001001534380	3 (1R)	-	-	1.0	-
LZ3	Seine Net	1	15/Aug/18	12:45	15/Aug/18	12:55	-	18	NRPK	294	163.50	989001001534454	4 (2R)	-	-	1.0	-
LZ3	Seine Net	2	15/Aug/18	12:57	15/Aug/18	13:07	-	-	NFC	-	-	-	-	-	-	1.0	-
LZ3	Seine Net	3	15/Aug/18	13:09	15/Aug/18	13:18	-	19	NRPK	362	324.10	989001001534365	4 (1R)	-	-	1.0	-
LZ3	Seine Net	3	15/Aug/18	13:09	15/Aug/18	13:18	152	-	NRPK	95	3.60	-	-	-	-	1.0	-
LZ3	Seine Net	3	15/Aug/18	13:09	15/Aug/18	13:18	153	-	NRPK	94	5.10	-	-	-	-	1.0	-
LZ4	Boat EF	1	16/Aug/18	15:48	16/Aug/18	15:54	-	339	YLPR	62	3.00	-	-	-	-	-	126
LZ4	Boat EF	1	16/Aug/18	15:48	16/Aug/18	15:54	-	340	SPSH	73	4.70	-	-	-	-	-	126
LZ4	Boat EF	1	16/Aug/18	15:48	16/Aug/18	15:54	-	341	YLPR	113	18.70	-	-	-	-	-	126
LZ4	Hoop Net	1	13/Aug/18	13:27	14/Aug/18	10:17	-	4	NRPK	289	151.70	989001001534434	5 (1R)	20.83	-	-	-
LZ4	Minnow Trap	1	13/Aug/18	11:28:00 AM	14/Aug/18	07:45	5	-	NRPK	82	3.27			20.28	-	-	-
LZ4	Minnow Trap	2	13/Aug/18	11:28	14/Aug/18	07:45	-	-	NFC	-	-	-	-	20.28	-	-	-
LZ4	Minnow Trap	3	13/Aug/18	11:28	14/Aug/18	07:45	-	-	NFC	-	-	-	-	20.28	-	-	-
LZ4	Minnow Trap	4	13/Aug/18	11:28	14/Aug/18	07:45	-	-	NFC	-	-	-	-	20.28	-	-	-
LZ4	Minnow Trap	5	13/Aug/18	11:28:00 AM	14/Aug/18	7:45:00 AM	-	-	NFC	-	-	-	-	20.28	-	-	-
LZ4	Minnow Trap	6	14/Aug/18	9:27:00 AM	15/Aug/18	7:47:00 AM	-	-	NFC	-	-	-	-	22.33	-	-	-
LZ4	Minnow Trap	7	14/Aug/18	09:27	15/Aug/18	7:47:00 AM	-	-	NFC	-	-	-	-	22.33	-	-	-
LZ4	Minnow Trap	8	14/Aug/18	9:27:00 AM	15/Aug/18	7:47:00 AM	-	-	NFC	-	-	-	-	22.33	-	-	-
LZ4	Minnow Trap	9	14/Aug/18	09:27	15/Aug/18	07:47	-	-	NFC	-	-	-	-	22.33	-	-	-
LZ4	Minnow Trap	10	14/Aug/18	09:27	15/Aug/18	07:47	-	-	NFC	-	-	-	-	22.33	-	-	-
LZ4	Seine Net	1	15/Aug/18	15:08	15/Aug/18	15:14	181	-	SPSH	34	0.35	-	-	-	-	1.0	-
LZ4	Seine Net	1	15/Aug/18	15:08	15/Aug/18	15:14	182	-	SPSH	26	0.27	-	-	-	-	1.0	-
LZ4	Seine Net	1	15/Aug/18	15:08	15/Aug/18	15:14	183	-	SPSH	20	0.21	-	-	-	-	1.0	-
LZ4	Seine Net	1	15/Aug/18	15:08	15/Aug/18	15:14	184	-	YLPR	73	5.20	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	155	-	SPSH	28	0.16	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	156	-	SPSH	35	0.51	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	157	-	SPSH	26	0.26	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	158	-	SPSH	31	0.28	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	159	-	SPSH	30	0.38	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	160	-	SPSH	38	0.64	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	161	-	SPSH	26	0.26	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	162	-	SPSH	28	0.27	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	163	-	SPSH	29	0.28	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	164	-	SPSH	34	0.59	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	165	-	SPSH	42	0.83	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	166	-	YLPR	130	30.36	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	167	-	YLPR	67	4.35	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	168	-	YLPR	117	22.09	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	169	-	YLPR	130	29.03	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	170	-	YLPR	126	25.56	-	-	-	-	1.0	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	171	-	YLPR	105	18.92	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	172	-	YLPR	116	19.46	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	173	-	YLPR	134	30.46	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	174	-	YLPR	140	33.90	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	175	-	YLPR	75	4.88	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	176	-	YLPR	70	3.92	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	177	-	YLPR	65	3.14	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	178	-	YLPR	73	4.67	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	179	-	SPSH	34	0.40	-	-	-	-	1.0	-
LZ4	Seine Net	2	15/Aug/18	15:15	15/Aug/18	15:27	180	-	YLPR	120	22.06	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	185	-	YLPR	62	2.78	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	186	-	YLPR	67	3.86	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	187	-	YLPR	72	5.18	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	188	-	YLPR	66	2.98	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	189	-	YLPR	75	5.21	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	190	-	YLPR	64	3.13	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	191	-	YLPR	73	4.66	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	192	-	YLPR	68	3.93	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	193	-	YLPR	67	3.20	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	194	-	YLPR	76	6.18	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	195	-	SPSH	85	7.59	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	196	-	SPSH	76	5.42	-	-	-	-	1.0	-
LZ4	Seine Net	3	15/Aug/18	15:28	15/Aug/18	16:38	197	-	EMSH	49	1.36	-	-	-	-	1.0	-
LZ5	Boat EF	1	16/Aug/18	15:57	16/Aug/18	16:02	342	-	YLPR	130	25.50	-	-	-	-	-	125
LZ5	Hoop Net	1	14/Aug/18	12:10:00 PM	15/Aug/18	09:04	-	15	NRPK	307	199.70	989001001534441	3 (1R)	20.90	-	-	-
LZ5	Hoop Net	2	15/Aug/18	09:04	16/Aug/18	8:35:00 AM	-	26	NRPK	704	2530.00	989001001534430	7	23.52	-	-	-
LZ5	Hoop Net	2	15/Aug/18	9:04:00 AM	16/Aug/18	8:35:00 AM	-	27	NRPK	695	1980.00	989001001534372	7 (5R)	23.52	-	-	-
LZ5	Minnow Trap	1	13/Aug/18	11:37:00 AM	14/Aug/18	07:50	-	-	NFC	-	-	-	-	20.22	-	-	-
LZ5	Minnow Trap	2	13/Aug/18	11:37	14/Aug/18	07:50	-	-	NFC	-	-	-	-	20.22	-	-	-
LZ5	Minnow Trap	3	13/Aug/18	11:37:00 AM	14/Aug/18	7:50:00 AM	-	-	NFC	-	-	-	-	20.22	-	-	-
LZ5	Minnow Trap	4	13/Aug/18	11:37	14/Aug/18	07:50	-	-	NFC	-	-	-	-	20.22	-	-	-
LZ5	Minnow Trap	5	13/Aug/18	11:37	14/Aug/18	07:50	-	-	NFC	-	-	-	-	20.22	-	-	-
LZ5	Minnow Trap	6	14/Aug/18	09:44	15/Aug/18	07:52	-	-	NFC	-	-	-	-	22.13	-	-	-
LZ5	Minnow Trap	7	14/Aug/18	09:44	15/Aug/18	7:52:00 AM	92	-	NRPK	109	7.76	-	-	22.13	-	-	-
LZ5	Minnow Trap	8	14/Aug/18	09:44	15/Aug/18	07:52	-	-	NFC	-	-	-	-	22.13	-	-	-
LZ5	Minnow Trap	9	14/Aug/18	9:44:00 AM	15/Aug/18	07:52	-	-	NFC	-	-	-	-	22.13	-	-	-
LZ5	Minnow Trap	10	14/Aug/18	9:44:00 AM	15/Aug/18	07:52	-	-	NFC	-	-	-	-	22.13	-	-	-
LZ5	Seine Net	1	15/Aug/18	16:39	15/Aug/18	16:49	-	-	NFC	-	-	-	-	-	-	1.0	-
LZ5	Seine Net	2	15/Aug/18	16:50	15/Aug/18	17:02	-	-	NFC	-	-	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	198	-	YLPR	109	14.93	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	199	-	YLPR	109	14.40	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	200	-	YLPR	65	3.70	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	201	-	YLPR	67	3.46	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	202	-	YLPR	72	4.27	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	203	-	YLPR	63	3.03	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	204	-	YLPR	66	3.43	-	-	-	-	1.0	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	205	-	YLPR	67	3.32	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	206	-	YLPR	64	3.00	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	207	-	YLPR	65	2.98	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	208	-	YLPR	65	3.50	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	209	-	YLPR	65	3.37	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	210	-	SPSH	65	3.79	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	211	-	YLPR	99	12.62	-	-	-	-	1.0	-
LZ5	Seine Net	3	15/Aug/18	17:03	15/Aug/18	17:45	212	-	YLPR	57	2.74	-	-	-	-	1.0	-
LZ6	Boat EF	1	16/Aug/18	15:04	16/Aug/18	15:10	-	-	NFC	-	-	-	-	-	-	-	128
LZ6	Hoop Net	1	13/Aug/18	1:55:00 PM	14/Aug/18	11:00:00 AM	7	-	NRPK	150	18.50	-	-	21.08	-	-	-
LZ6	Minnow Trap	1	13/Aug/18	12:41:00 PM	14/Aug/18	8:01:00 AM	-	-	NFC	-	-	-	-	19.33	-	-	-
LZ6	Minnow Trap	2	13/Aug/18	12:41:00 PM	14/Aug/18	8:01:00 AM	-	-	NFC	-	-	-	-	19.33	-	-	-
LZ6	Minnow Trap	3	13/Aug/18	12:41	14/Aug/18	8:01:00 AM	6	-	NRPK	93	4.70	-	-	19.33	-	-	-
LZ6	Minnow Trap	4	13/Aug/18	12:41	14/Aug/18	08:01	-	-	NFC	-	-	-	-	19.33	-	-	-
LZ6	Minnow Trap	5	13/Aug/18	12:41	14/Aug/18	8:01:00 AM	-	-	NFC	-	-	-	-	19.33	-	-	-
LZ6	Minnow Trap	6	14/Aug/18	9:54:00 AM	15/Aug/18	8:05:00 AM	-	-	NFC	-	-	-	-	22.18	-	-	-
LZ6	Minnow Trap	7	14/Aug/18	09:54	15/Aug/18	08:05	-	-	NFC	-	-	-	-	22.18	-	-	-
LZ6	Minnow Trap	8	14/Aug/18	09:54	15/Aug/18	08:05	-	-	NFC	-	-	-	-	22.18	-	-	-
LZ6	Minnow Trap	9	14/Aug/18	09:54	15/Aug/18	8:05:00 AM	-	-	NFC	-	-	-	-	22.18	-	-	-
LZ6	Minnow Trap	10	14/Aug/18	09:54	15/Aug/18	8:05:00 AM	-	-	NFC	-	-	-	-	22.18	-	-	-
LZ6	Seine Net	1	14/Aug/18	16:19	14/Aug/18	16:42	22	-	NRPK	95	4.80	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	23	-	SPSH	38	0.53	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	24	-	SPSH	40	0.52	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	25	-	SPSH	39	0.56	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	26	-	SPSH	46	0.96	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	27	-	SPSH	40	0.67	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	28	-	SPSH	39	0.75	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	29	-	SPSH	39	0.60	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	30	-	SPSH	35	0.44	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	31	-	SPSH	37	0.58	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	32	-	SPSH	39	0.60	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	33	-	SPSH	36	0.64	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	34	-	SPSH	44	0.95	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	35	-	SPSH	42	0.74	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	36	-	SPSH	37	0.63	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	37	-	YLPR	73	4.14	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	38	-	YLPR	67	3.23	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	39	-	YLPR	74	4.63	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	40	-	YLPR	66	3.20	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	41	-	YLPR	65	3.15	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	42	-	YLPR	66	3.34	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	43	-	YLPR	68	3.85	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	44	-	YLPR	75	4.30	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	45	-	YLPR	70	4.14	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	46	-	YLPR	66	3.53	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	47	-	YLPR	62	2.86	-	-	-	-	1.0	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	48	-	YLPR	66	3.46	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	49	-	YLPR	70	4.28	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	50	-	YLPR	110	8.76	-	-	-	-	1.0	-
LZ6	Seine Net	2	14/Aug/18	16:43	14/Aug/18	17:03	51	-	YLPR	113	9.30	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	52	-	SPSH	27	0.21	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	53	-	SPSH	44	0.62	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	54	-	SPSH	31	0.16	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	55	-	SPSH	32	0.24	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	56	-	SPSH	36	0.59	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	57	-	SPSH	33	0.48	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	58	-	SPSH	37	0.50	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	59	-	SPSH	31	0.36	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	60	-	SPSH	28	0.18	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	61	-	SPSH	32	0.36	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	62	-	SPSH	40	0.70	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	63	-	SPSH	35	0.39	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	64	-	SPSH	43	0.64	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	65	-	SPSH	26	0.14	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	66	-	SPSH	34	0.28	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	67	-	SPSH	30	0.23	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	68	-	SPSH	35	0.30	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	69	-	SPSH	40	0.95	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	70	-	SPSH	34	0.41	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	71	-	SPSH	30	0.26	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	72	-	SPSH	34	0.41	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	73	-	SPSH	31	0.27	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	74	-	SPSH	33	0.31	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	75	-	SPSH	35	0.41	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	76	-	SPSH	35	0.47	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	77	-	SPSH	35	0.41	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	78	-	SPSH	34	0.29	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	79	-	SPSH	30	0.16	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	80	-	SPSH	26	0.09	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	81	-	SPSH	41	0.45	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	82	-	SPSH	41	0.61	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	83	-	SPSH	26	0.26	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	84	-	SPSH	35	0.42	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	85	-	SPSH	32	0.31	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	86	-	SPSH	37	0.56	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	87	-	SPSH	41	0.75	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	88	-	SPSH	44	0.43	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	89	-	SPSH	36	0.39	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	90	-	SPSH	33	0.35	-	-	-	-	1.0	-
LZ6	Seine Net	3	14/Aug/18	17:04	14/Aug/18	17:29	91	-	SPSH	36	0.44	-	-	-	-	1.0	-
PZ1	Angling	1	13/Aug/18	15:30	13/Aug/18	15:45	-	-	NFC	-	-	-	-	-	45	-	-
PZ1	Angling	2	14/Aug/18	11:39	14/Aug/18	11:54	-	5	NRPK	604	1285.00	MORT	4(6R)	-	30	-	-

Table A5.58 Fish data collected for No Net Loss Lake, Summer 2018.

Location	Fishing Gear	Trap/ Pass #	Start Date	Start Time	End Date	End Time	Fish ID		Species	Length (mm)	Weight (g)	Tag Number	Age	Effort			
							Small bodied	Large bodied						Hours	Minutes	Pulls	Seconds
PZ1	Angling	3	13/Aug/18	15:45	13/Aug/18	16:00	-	-	NFC	-	-	-	-	-	30	-	-
PZ1	Angling	4	13/Aug/18	16:00	13/Aug/18	16:15	-	-	NFC	-	-	-	-	-	30	-	-
PZ1	Angling	5	13/Aug/18	16:15	13/Aug/18	16:30	-	1	NRPK	532	988.20	989001001534409	6 (4R)	-	30	-	-
PZ1	Angling	5	13/Aug/18	16:15	13/Aug/18	16:30	-	2	NRPK	490	729.10	989001001534413	6 (3R)	-	30	-	-
PZ1	Angling	6	14/Aug/18	11:58	14/Aug/18	12:13	-	-	NFC	-	-	-	-	-	30	-	-
PZ1	Angling	7	14/Aug/18	13:30	14/Aug/18	13:45	-	8	NRPK	273	127.30	989001001534437	4 (1R)	-	30	-	-
PZ1	Angling	8	14/Aug/18	14:15	14/Aug/18	14:30	-	-	NFC	-	-	-	-	-	30	-	-
PZ1	Angling	9	14/Aug/18	14:32	14/Aug/18	14:47	-	-	NFC	-	-	-	-	-	30	-	-
PZ1	Angling	10	15/Aug/18	17:50	15/Aug/18	18:05	-	21	NRPK	620	1499.90	989001001534369	7 (3R)	-	45	-	-
PZ1	Angling	11	15/Aug/18	18:05	15/Aug/18	18:20	-	23	NRPK	530	1035.30	989001001534383	6 (3R)	-	45	-	-
PZ1	Angling	12	15/Aug/18	18:20	15/Aug/18	18:35	-	24	NRPK	522	967.80	989001001534418	6 (3R)	-	45	-	-
PZ1	Angling	12	15/Aug/18	18:20	15/Aug/18	18:35	-	25	NRPK	532	988.20	989001001534409	-	-	45	-	-
PZ1	Angling	13	15/Aug/18	18:35	15/Aug/18	18:50	-	-	NFC	-	-	-	-	-	45	-	-
PZ1	Angling	14	15/Aug/18	18:50	15/Aug/18	19:05	-	37	NRPK	551	1100.00	-	-	-	45	-	-
PZ1	Angling	14	15/Aug/18	18:50	15/Aug/18	19:05	-	38	NRPK	653	1920.00	989001001534366	9 (5R)	-	45	-	-
PZ1	GN	1	13/Aug/18	14:30	13/Aug/18	16:30	1	-	YLPR	117	19.26	-	-	-	120	-	-
PZ1	GN	1	13/Aug/18	2:30:00 PM	13/Aug/18	4:30:00 PM	2	-	YLPR	117	17.97	-	-	-	120	-	-
PZ1	GN	1	13/Aug/18	14:30	13/Aug/18	4:30:00 PM	3	-	YLPR	114	16.46	-	-	-	120	-	-
PZ1	GN	1	13/Aug/18	14:30	13/Aug/18	4:30:00 PM	4	-	YLPR	117	18.02	-	-	-	120	-	-
PZ1	GN	2	14/Aug/18	12:55	14/Aug/18	2:55:00 PM	12	-	YLPR	132	23.12	-	-	-	120	-	-
PZ2	Angling	1	13/Aug/18	16:30	13/Aug/18	16:45	-	-	NFC	-	-	-	-	-	45	-	-
PZ2	Angling	2	13/Aug/18	16:45	13/Aug/18	17:00	-	-	NFC	-	-	-	-	-	45	-	-
PZ2	Angling	3	15/Aug/18	19:05	15/Aug/18	19:20	-	22	NRPK	546	1262.20	989001001534404	6 (3R)	-	45	-	-
PZ2	Angling	4	15/Aug/18	19:20	15/Aug/18	19:35	-	-	NFC	-	-	-	-	-	15	-	-
PZ2	Angling	5	15/Aug/18	19:35	15/Aug/18	19:50	-	-	NFC	-	-	-	-	-	15	-	-
PZ2	GN	1	14/Aug/18	14:38	14/Aug/18	16:35	-	-	NFC	-	-	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	-	6	NRPK	548	1615.10	989001001534435	6 (4R)	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	2:48:00 PM	-	7	YLPR	161	58.53	989001001534394	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	-	9	YLPR	174	70.55	989001001534453	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	2:48:00 PM	-	10	NRPK	555	1268.20	989001001534392	6 (4R)	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	2:48:00 PM	-	11	YLPR	165	60.57	989001001534395	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	14:48	8	-	YLPR	105	12.99	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	2:48:00 PM	9	-	YLPR	116	17.66	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	2:48:00 PM	10	-	YLPR	141	36.16	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	13	-	YLPR	111	17.38	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	14	-	YLPR	119	18.36	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	14:48	15	-	YLPR	110	13.66	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48:00 PM	14/Aug/18	2:48:00 PM	16	-	YLPR	118	18.94	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	17	-	YLPR	117	18.13	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	18	-	YLPR	122	20.83	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	19	-	YLPR	120	19.68	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	20	-	YLPR	130	28.51	-	-	-	120	-	-
PZ2	GN	2	14/Aug/18	12:48	14/Aug/18	14:48	21	-	YLPR	120	20.65	-	-	-	120	-	-

Table A5.59 Fish data collected for Creek A and the outlet channel, September 2018.

Location	Fishing Gear	Habitat Unit	Fish ID	Species	Length (mm)	Weight (g)	Tag Number	Age	Effort (hrs/secs)
IC-1	Backpack EF	HU1	-	-	-	-	-	-	344
OC2	Backpack EF	HU1	1	NRPK	111	11.57	-	-	332
OC2	Backpack EF	HU1	2	SLSC	100	13.22	-	-	332
OC2	Backpack EF	HU2	-	-	-	-	-	-	145
OC2	Backpack EF	HU3	3	BURB	187	36.02	989001001534358	1	172
OC2	Backpack EF	HU4	4	BURB	111	9.09	-	-	180
OC2	Backpack EF	HU5	5	LNSC	117	19.78	-	-	251
OC2	Backpack EF	HU6	6	NRPK	112	10.52	-	-	85
OC2	Backpack EF	HU7	-	-	-	-	-	-	45
OC3	Backpack EF	HU1	1	BURB	158	19.02	989001001534416	1	459
OC3	Backpack EF	HU1	2	BURB	149	16.4	-	-	459
OC3	Backpack EF	HU1	3	LKCH	103	11.16	-	-	459
OC3	Backpack EF	HU2	-	-	-	-	-	-	122
OC3	Backpack EF	HU3	4	BURB	210	49.94	989001001534297	1	216
OC3	Backpack EF	HU4	5	LNSC	84	7.02	-	-	66

Appendix A6

Quality Assurance and Quality Control Procedures

A6.0 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

Quality assurance and quality control (QA/QC) is a documentation system used to review and audit data management and reporting activities. The objective of the procedures is to confirm to the client that defined standards of quality are being achieved. Quality control refers to the specific methodological techniques that are implemented within the quality assurance plan. A successfully implemented QA/QC program will ensure that field and analytical methods are undertaken in a scientifically-defensible and repeatable manner. A variety of quality control procedures were used during implementation of the 2018 No Not Loss Lake (NNLL) monitoring program, with the objective of providing incremental checks and balances throughout the study design, data collection, data analysis, and reporting.

A6.1 METHODS

Hatfield prepared the NNLL Field Protocols manual (Hatfield 2015) for field data collection activities, to ensure a standardized approach is used by all personnel undertaking monitoring activities at the NNLL. The document identifies the specific methods for sample collection, sample labeling and handling, equipment calibration and use, and record-keeping. The sampling manual is reviewed and updated to incorporate new or modified monitoring activities on an annual basis.

In advance of each sampling program, a set of field work instructions (FWI) was provided to and reviewed by each field crew member. These documents provided a detailed summary of the sampling tasks to be undertaken and the rationale for collecting these data.

A6.1.1 Surface Hydrology

Field activities, including stream discharge measurements and water level surveys, were performed in accordance with standard procedures listed in BC MOE (2009) and WSC (2001), and are summarized in the NNLL Field Protocols manual (Hatfield 2015). QA/QC tests were conducted on all field equipment prior to their use on each field program to decrease sources of error during field measurements. These tests include: manufacturer-provided QA/QC tests of all flow meters, as well as performing 2-Peg Tests on survey levels used during the field programs. Any field equipment not passing QA/QC tests were calibrated, re-checked, or replaced prior to proceeding with field measurements.

During data collection, every effort was made to ensure 20 discharge measurement verticals were acquired and that each vertical represented less than 10% of the total flow for the stream cross section. Surveys of water level elevation were conducted such that survey error did not exceed 0.004 m.

Hydrometric station equipment was also assessed and maintained on a field trip basis, or as necessary. Water level sensors at each of the four hydrometric stations, as well as all sensors at the climate station, each have a sensor calibration schedule that was followed to ensure collected data are reliable. These calibration schedules are based upon the manufacturer's recommendations for each given sensor.

Data management and production included stringent QA/QC procedures, which also align with BC MOE, (2009) and WSC (2001) procedures. This included the checking of all field data by a technician who did not collect the data. Water level time series were checked on a monthly basis to ensure completeness of data

records, as well as the proper functioning of each hydrometric station. This was completed using Aquarius Time-Series® Version 3.10.71 (Aquatic Informatics) software. Following data management and production, all collected and processed data were checked by a senior reviewer before release, and subsequent use.

A6.1.2 Water Quality

To assess potential contamination resulting from field collection methods, samples of deionized water were prepared in the field, and submitted "blind" to the consulting laboratories for analysis along with the ambient water samples. Laboratory-prepared travel blanks were also submitted for each sampling program, to identify potential contamination resulting from sample handling and analysis by the laboratories.

Travel blanks were collected during the winter and summer sampling sessions, while a field blank was collected during the spring and fall sampling session. Screening for potentially contaminated samples was achieved by comparing field blank results to analytical detection limits. Blanks with analyte (with the exception of pH) concentrations below or near the detection limits represent samples that were collected and handled properly. Blanks with contaminant concentrations greater than five times the detection limits were identified as potentially contaminated during sample collection, shipping, or analysis.

A review of field and travel blank results was conducted to identify any variables with recurring elevated levels, and to determine whether incidences of potential contamination resulted during sample collection (i.e., elevated concentrations in field blanks only); or during laboratory analysis (i.e., elevated concentrations in field and travel blanks or travel blanks only).

Duplicate samples were collected from station PZ-1 during each sampling session. Duplicate samples were taken to assess environmental heterogeneity. Analytical results for duplicate samples were compared, and the relative percent difference (RPD, difference between data values/mean of data values, multiplied by 100%) was calculated for each analyte. RPDs greater than 20% were noted as potentially unacceptable levels of precision. However, because precision decreases as the analyte concentration approaches the detection limit, RPDs greater than 20% were considered to be of significance only if analyte concentrations in both samples were greater than five times the detection limit.

In addition to quality control sample analyses, the following field procedures were used to prevent contamination during sample collection:

- All sample bottles were sterilized and provided by the respective analytical laboratories;
- Sample bottles were kept inside a clean cooler prior to use and while in the boat;
- Field staff wore powder-free latex gloves while collecting sample water;
- Prior to sampling, a scrub brush and Liquinox® were used to clean the inside of the composite bucket and rinsed thoroughly with ambient water;
- Near-bottom water was collected using a clean, triple-rinsed Van Dorn sampler, with samples transferred directly to lab supplied bottles;
- Care was taken not to disturb sediments during sampling, by avoiding bottom contact with the Van Dorn sampler;

- After collecting the composite sample with the Van Dorn, the outside of each sample bottle was rinsed with ambient water prior to dipping the sample bottle into the composite bucket; and
- Dissolved oxygen (DO) titrations were completed in the field, to ensure YSI meter readings were accurate.

For continuous water quality monitoring, calibration of the datasondes were conducted on a monthly basis to ensure accurate measurements were recorded.

A6.1.3 Sediment Quality

A number of procedures were followed in the field to prevent sediment sample contamination. Before sample collections, all equipment (spoons, pans, dredge) were cleaned using four steps:

1. Equipment was cleaned with a metals-free soap (i.e., Liquinox®);
2. Equipment was rinsed with environmental-grade hexane;
3. Equipment was rinsed with environmental-grade acetone (these steps remove any organic residues); and
4. Equipment was rinsed three times with ambient water (i.e., lake water).

Only grab samples that did not contain large, foreign objects, obtained an adequate penetration depth, and were not over filled or leaking, were used. Sediments were transferred directly from the dredge to a pan, where they were homogenized with a large spoon. All sampling equipment that came in direct contact with the sample was constructed from stainless steel. As an additional precaution, staff wore powder-free latex gloves throughout the equipment cleaning and sample collection process.

A duplicate sample was taken at the pelagic station to assess environmental heterogeneity. Analytical results for duplicate samples were compared, and the RPD was calculated for each analyte.

A6.1.4 Benthic Invertebrate Communities

Field methods used for invertebrate collection followed accepted methods for environmental effects monitoring (Environment Canada 2010).

Taxonomic samples were sorted and identified by Dr. Jack Zloty of Summerland, BC. Laboratory methods used by Dr. Zloty in 2018 included resorting of 5% of samples from the No Net Loss Lake monitoring program, as a confirmation of the overall sorting efficiency of all samples. In 2018, one sample from the littoral zone, and one from the pelagic zone were re-sorted. Sorted portions were verified by an independent analyst. As a result of large volumes of organic material and low abundance in some samples collected from depositional areas, a minimum removal efficiency of 90% was considered acceptable. This objective is considered acceptable by Environment Canada under current Environmental Effects Monitoring (EEM) strategies (Environment Canada 2010).

A6.1.5 Data Management

Quality control procedures for data entry and analysis included a 100% re-check on all hardcopy data, to ensure accurate transcription from field data sheets to digital formats. Data were also displayed graphically to visually assess for the presence of outliers caused by field data transcription errors.

Hatfield has developed a Quality System Procedure (QSP) for data transcribed from laboratory reports whereby a random sample of transcribed data points is checked against the laboratory report. This QSP includes a standard formula for determining the appropriate number of data points to be checked, with the aim of obtaining an error rate of no more than 2%. If more than 2% of the data is erroneous, the errors are corrected and the process repeated until an error rate of less than 2% is achieved.

A6.2 RESULTS

A6.2.1 Water Quality

A6.2.1.1 Trip and Field Blanks

A trip blank or a field blank was collected and analyzed during each sampling event at the NNLL (Table A6.1 and Table A6.2). There were no concentrations that were greater than five times the detection limit in any of the trip blanks or field blanks.

Table A6.1 Concentrations of water quality variables in trip blanks collected during the No Net Loss Lake Monitoring Program, Fort Hills Oil Sands Project, 2018.

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			14-Mar-18	19-Jul-18
Conventional Variables				
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0
Alkalinity, Total (as $CaCO_3$)	mg/L	2 or 5	<2.0	<2.0
Color, True	C.U.	2	<2.0	<2.0
Conductivity (EC)	µS/cm	2	<2.0	<2.0
Dissolved Organic Carbon	mg/L	1	<1.0	<1.0
Hardness (as $CaCO_3$)	mg/L	1.3	<1.3	<1.0
pH	pH	0.1		
Total Dissolved Solids	mg/L	10	<10.0	<10.0
Total Organic Carbon	mg/L	1	<1.0	<1.0
Total Suspended Solids	mg/L	3	<3.0	<3.0
Dissolved Metals				
Aluminum (Al)	mg/L	0.001	<0.001	<0.001
Antimony (Sb)	mg/L	0.00001	<0.00001	<0.00001
Arsenic (As)	mg/L	0.00005	<0.00005	<0.00005
Barium (Ba)	mg/L	0.0001	<0.0001	<0.0001
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005

\# Analytics > 5 times the detection limit.

Table A6.1 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			14-Mar-18	19-Jul-18
Dissolved Metals (Cont'd.)				
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.005	<0.005	0.0085
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005
Calcium (Ca)	mg/L	0.05	<0.05	<0.05
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005
Copper (Cu)	mg/L	0.0002	<0.0002	<0.0002
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005
Iron (Fe)	mg/L	0.03	<0.03	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.0002	<0.0002	<0.0002
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Manganese (Mn)	mg/L	0.0002	<0.0002	<0.0002
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005
Methyl Mercury	µg/L	0.00005	<0.00005	<0.00002
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0002	<0.0002	<0.0002
Phosphorus (P)	mg/L	0.3	<0.3	<0.3
Potassium (K)	mg/L	2	<2.0	<2.0
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005
Rubidium (Rb)	mg/L	0.00002	<0.00002	<0.00002
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002
Silicon (Si)	mg/L	0.05	<0.05	<0.05
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005
Sodium (Na)	mg/L	2	<2.0	<2.0
Strontium (Sr)	mg/L	0.00005	<0.00005	<0.00005
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001
Thallium (Tl)	mg/L	0.000002	<0.000002	<0.000002
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001
Uranium (U)	mg/L	0.000002	<0.000002	<0.000002
Vanadium (V)	mg/L	0.00005	<0.00005	<0.00005
Yttrium (Y)	mg/L	0.000005	<0.000005	<0.000005

\# Analytics > 5 times the detection limit.

Table A6.1 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			14-Mar-18	19-Jul-18
Dissolved Metals (Cont'd.)				
Zinc (Zn)	mg/L	0.001	<0.001	0.002
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005
General Organics				
Benzene	mg/L	0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005
F1(C6-C10)	mg/L	0.1	<0.1	<0.1
F1-BTEX	mg/L	0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.1	<0.1	<0.1
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005
Naphthenic Acids	mg/L	1	<1.0	<1.0
o-Xylene	mg/L	0.0005	<0.0005	<0.0005
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001
Toluene	mg/L	0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.00071	<0.00071	<0.00071
Major Ions				
Bicarbonate (HCO_3)	mg/L	5	<5.0	<5.0
Calcium (Ca)	mg/L	0.5	<0.5	<0.5
Carbonate (CO_3)	mg/L	5	<5.0	<5.0
Chloride (Cl)	mg/L	0.5	<0.5	<0.5
Hydroxide (OH)	mg/L	5	<5.0	<5.0
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Potassium (K)	mg/L	0.5	<0.5	<0.5
Sodium (Na)	mg/L	1	<1.0	<1.0
Sulfate (SO_4)	mg/L	0.3	<0.3	<0.3
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015
Nutrients and BOD				
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05
Biochemical Oxygen Demand	mg/L	2	<2.0	<2.0
Nitrate (as N)	mg/L	0.02	<0.01	<0.01
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022
Nitrite (as N)	mg/L	0.01	<0.01	<0.01
Phosphorus (P)-Total	mg/L	0.001	<0.001	<0.001

\# Analytics > 5 times the detection limit.

Table A6.1 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			14-Mar-18	19-Jul-18
Nutrients and BOD (Cont'd.)				
Phosphorus (P)-Total Dissolved	mg/L	0.001	<0.001	<0.001
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	<0.2
Polycyclic Aromatic Hydrocarbons				
1-Methylnaphthalene	µg/L	0.02	<0.02	<0.02
2-Methylnaphthalene	µg/L	0.02	<0.02	<0.02
Acenaphthene	µg/L	0.02	<0.02	<0.02
Acenaphthylene	µg/L	0.02	<0.02	<0.02
Acridine	µg/L	4 or 12	<4.0	<4.0
Anthracene	µg/L	0.012	<0.012	<0.012
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018
Benzo(a)pyrene	µg/L	0.005	<0.005	<0.005
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02
Chrysene	µg/L	0.02	<0.02	<0.02
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02
Fluoranthene	µg/L	0.02	<0.02	<0.02
Fluorene	µg/L	0.02	<0.02	<0.02
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02
Naphthalene	µg/L	0.05	<0.05	<0.05
Phenanthrene	µg/L	0.02	<0.02	<0.02
Pyrene	µg/L	0.02	<0.02	<0.02
Quinoline	µg/L	0.04	<0.04	<0.04
Total Metals				
Aluminum (Al)	mg/L	0.003	<0.003	<0.003
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003
Arsenic (As)	mg/L	0.00005	<0.00005	<0.00005
Barium (Ba)	mg/L	0.0001	<0.0001	<0.0001
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.01	<0.01	<0.01
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005
Calcium (Ca)	mg/L	0.05	<0.05	<0.05
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005

Analytics > 5 times the detection limit.

Table A6.1 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			14-Mar-18	19-Jul-18
Total Metals (Cont'd.)				
Copper (Cu)	mg/L	0.0005	<0.0005	<0.0005
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005
Iron (Fe)	mg/L	0.03	<0.03	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.0004	<0.0004	<0.0004
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Manganese (Mn)	mg/L	0.0002	<0.0002	<0.0002
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005
Methyl Mercury	µg/L	0.00005	<0.00005	<0.00002
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0002	<0.0002	<0.0002
Phosphorus (P)	mg/L	0.3	<0.3	<0.3
Potassium (K)	mg/L	2	<2.0	<2.0
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005
Rubidium (Rb)	mg/L	0.00002	<0.00002	<0.00002
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002
Silicon (Si)	mg/L	0.05	<0.10	<0.10
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005
Sodium (Na)	mg/L	2	<2.0	<2.0
Strontium (Sr)	mg/L	0.0002	0.0002	0.0002
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001
Uranium (U)	mg/L	0.000002	<0.000002	<0.000002
Vanadium (V)	mg/L	0.00005	<0.00005	<0.00005
Yttrium (Y)	mg/L	0.000005	<0.000005	<0.000005
Zinc (Zn)	mg/L	0.003	<0.003	<0.003
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005

Analytics > 5 times the detection limit.

Table A6.2 Concentrations of water quality variables in field blanks collected during the No Net Loss Lake Monitoring Program, Fort Hills Oil Sands Project, 2018.

Variable	Unit	Detection Limit	Concentrations in Field Blank	
			11-May-18	19-Sep-18
Conventional Variables				
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0
Alkalinity, Total (as $CaCO_3$)	mg/L	2	<2.0	<2.0
Color, True	C.U.	2	<2.0	<2.0
Conductivity (EC)	µS/cm	2	<2.0	<2.0
Dissolved Organic Carbon	mg/L	1	<1.0	<1.0
Hardness (as $CaCO_3$)	mg/L	0.5 or 1.3	<1.0	<1.0
pH	pH units	0.1	5.09	5.73
Total Dissolved Solids	mg/L	10	<10.0	<10.0
Total Organic Carbon	mg/L	1	<1.0	<1.0
Total Suspended Solids	mg/L	3	<3.0	<3.0
Dissolved Metals				
Aluminum (Al)	mg/L	0.001	<0.001	<0.001
Antimony (Sb)	mg/L	0.00001	<0.00001	<0.00001
Arsenic (As)	mg/L	0.00005	<0.00005	<0.00005
Barium (Ba)	mg/L	0.0001	<0.0001	<0.0001
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.005	<0.005	<0.005
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005
Calcium (Ca)	mg/L	0.05	<0.05	<0.05
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005
Copper (Cu)	mg/L	0.0002	<0.0002	<0.0002
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005
Iron (Fe)	mg/L	0.03	<0.03	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.0002	<0.0002	<0.0002
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Manganese (Mn)	mg/L	0.0002	<0.0002	<0.0002
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005
Methyl Mercury	µg/L	0.00002	<0.00002	<0.00002
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0002	<0.0002	<0.0002

Analytics > 5 times the detection limit.

Table A6.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank	
			11-May-18	19-Sep-18
Conventional Variables (Cont'd.)				
Phosphorus (P)	mg/L	0.3	<0.3	<0.3
Potassium (K)	mg/L	2	<2.0	<2.0
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005
Rubidium (Rb)	mg/L	0.00002	<0.00002	<0.00002
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002
Silicon (Si)	mg/L	0.05	<0.05	<0.05
Silver (Ag)	mg/L	0.000005	0.000005	<0.000005
Sodium (Na)	mg/L	2	<2.0	<2.0
Strontium (Sr)	mg/L	0.00005	<0.00005	<0.00005
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001
Thallium (Tl)	mg/L	0.000002	<0.000002	<0.000002
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001
Uranium (U)	mg/L	0.000002	<0.000002	<0.000002
Vanadium (V)	mg/L	0.00005	0.00005	<0.00005
Yttrium (Y)	mg/L	0.000005	<0.000005	<0.000005
Zinc (Zn)	mg/L	0.001	<0.001	<0.001
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005
General Organics				
Benzene	mg/L	0.0005	<0.0005	<0.0005
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005
F1(C6-C10)	mg/L	0.1	<0.1	<0.1
F1-BTEX	mg/L	0.1	<0.1	<0.1
F2 (>C10-C16)	mg/L	0.1	<0.1	<0.1
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005
Naphthenic Acids	mg/L	1	1.2	1.0
o-Xylene	mg/L	0.0005	<0.0005	<0.0005
Phenols (4AAP)	mg/L	0.001	0.0010	<0.001
Toluene	mg/L	0.0005	<0.0005	<0.0005
Xylenes	mg/L	0.00071	<0.00071	<0.00071

Analytics > 5 times the detection limit.

Table A6.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank	
			11-May-18	19-Sep-18
Major Ions				
Bicarbonate (HCO_3)	mg/L	5	<5.0	<5.0
Calcium (Ca)	mg/L	0.5	<0.5	<0.5
Carbonate (CO_3)	mg/L	5	<5.0	<5.0
Chloride (Cl)	mg/L	0.5	<0.5	<0.5
Hydroxide (OH)	mg/L	5	<5.0	<5.0
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Potassium (K)	mg/L	0.5	<0.5	<0.1
Sodium (Na)	mg/L	1	<0.5	<0.5
Sulfate (SO_4)	mg/L	0.3	<0.3	<1.0
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015
Nutrients and BOD				
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05
Biochemical Oxygen Demand	mg/L	2	<2.0	<2.0
Nitrate (as N)	mg/L	0.02	<0.02	<0.02
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022
Nitrite (as N)	mg/L	0.01	<0.02	<0.01
Phosphorus (P)-Total	mg/L	0.001	<0.001	<0.001
Phosphorus (P)-Total Dissolved	mg/L	0.001	<0.001	0.0015
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	<0.2
Polycyclic Aromatic Hydrocarbons				
1-Methylnaphthalene	µg/L	0.02	<0.02	<0.02
2-Methylnaphthalene	µg/L	0.02	<0.02	<0.02
Acenaphthene	µg/L	0.02	<0.02	<0.02
Acenaphthylene	µg/L	0.02	<0.02	<0.02
Acridine	µg/L	4	<4.0	<4.0
Anthracene	µg/L	0.012	<0.012	<0.012
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018
Benzo(a)pyrene	µg/L	0.005	<0.005	<0.005
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02
Chrysene	µg/L	0.02	<0.02	<0.02
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02
Fluoranthene	µg/L	0.02	<0.02	<0.02
Fluorene	µg/L	0.02	<0.02	<0.02
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02

Analytics > 5 times the detection limit.

Table A6.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank	
			11-May-18	19-Sep-18
Naphthalene	µg/L	0.05	<0.05	<0.05
Phenanthrene	µg/L	0.02	<0.02	<0.02
Pyrene	µg/L	0.02	<0.02	<0.02
Quinoline	µg/L	0.04	<0.04	<0.04
Total Metals				
Aluminum (Al)	mg/L	0.003	<0.003	<0.003
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003
Arsenic (As)	mg/L	0.00005	<0.00005	<0.00005
Barium (Ba)	mg/L	0.0001	<0.000100	0.00019
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.01	<0.01	<0.01
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005
Calcium (Ca)	mg/L	0.05	<0.05	<0.05
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005
Copper (Cu)	mg/L	0.0005	<0.0005	<0.0005
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005
Iron (Fe)	mg/L	0.03	<0.03	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.0004	<0.0004	<0.0004
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Manganese (Mn)	mg/L	0.0002	<0.0002	<0.0002
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005
Methyl Mercury	µg/L	0.00002	<0.00002	<0.00002
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0002	<0.0002	<0.0002
Phosphorus (P)	mg/L	0.3	<0.3	<0.3
Potassium (K)	mg/L	2	<2.0	<2.0
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005
Rubidium (Rb)	mg/L	0.00002	<0.00002	<0.00002
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002
Silicon (Si)	mg/L	0.05	<0.10	<0.10
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005
Sodium (Na)	mg/L	2	<2.0	<2.0
Strontium (Sr)	mg/L	0.0002	<0.000200	<0.000200

Analytics > 5 times the detection limit.

Table A6.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank	
			11-May-18	19-Sep-18
Total Metals (Cont'd.)				
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001
Uranium (U)	mg/L	0.000002	<0.000002	<0.000002
Vanadium (V)	mg/L	0.00005	<0.00005	<0.00005
Yttrium (Y)	mg/L	0.000005	<0.000005	<0.000005
Zinc (Zn)	mg/L	0.003	<0.003	<0.003
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005

Analytics > 5 times the detection limit.

A6.2.1.2 Field Duplicates

Duplicate samples were collected at station PZ1 for all sampling events. Potential water quality contamination issues were identified during the winter, spring and summer sampling programs. Dissolved manganese, 2-methylnaphthalene, and naphthalene in winter, dissolved and total manganese in spring, and total phosphorus in summer differed by more than 20% between duplicate samples where both concentrations were more than five times the detection limit.

Potential sources of contamination were not apparent as field crews adhered to relevant SOPs for the collection of water quality samples and results of field blank analysis indicated that contamination due sampling procedures was unlikely.

Internal QA/QC results from ALS Laboratories did not indicate obvious contamination issues; therefore, water quality results from 2018 were considered valid and accurate (Table A6.3 to Table A6.6).

Table A6.3 Relative percent difference between duplicate water quality samples collected from station PZ1, winter 2018, Fort Hills Oil Sands Project.

Variable	Unit	Detection Limit	Winter		Relative Percent Difference (%)
			PZ1	Duplicate	
Conventional Variables					
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0	0.00
Alkalinity, Total (as $CaCO_3$)	mg/L	2	168	170	1.18
Color, True	C.U.	2	5.7	4.9	15.09
Conductivity (EC)	µS/cm	0.2	327	327	0.00
Dissolved Organic Carbon	mg/L	1	3.7	3.6	2.74
Hardness (as $CaCO_3$)	mg/L	1.3	153	158	3.22
pH	pH	0.1	8.19	8.17	0.24
Total Dissolved Solids	mg/L	20	191	193	1.04
Total Organic Carbon	mg/L	1	3.1	2.9	6.67
Total Suspended Solids	mg/L	3	4.6	4.9	6.32
Dissolved Metals					
Aluminum (Al)	mg/L	0.001	<0.001	<0.001	0.00
Antimony (Sb)	mg/L	0.00001	<0.00001	0.00001	0.00
Arsenic (As)	mg/L	0.00005	0.00016	0.000154	3.82
Barium (Ba)	mg/L	0.0001	0.0809	0.0949	15.93
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.005	0.0244	0.0264	7.87
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	46	50.0	8.33
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.3 (Cont'd.)

Variable	Unit	Detection Limit	Winter		Relative Percent Difference (%)
			PZ1	Duplicate	
Dissolved Metals (Cont'd.)					
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005	0.00
Copper (Cu)	mg/L	0.0002	<0.0002	<0.0002	0.00
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	<0.03	0.00
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0002	0.00463	0.00519	11.41
Magnesium (Mg)	mg/L	0.1	9.22	9.39	1.83
Manganese (Mn)	mg/L	0.0002	0.00144	0.00197	31.09
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005	0.00
Nickel (Ni)	mg/L	0.00005	0.000148	0.00016	7.79
Phosphorus (P)	mg/L	0.0002	<0.0002	<0.0002	0.00
Potassium (K)	mg/L	0.3	<0.3	<0.3	0.00
Rhenium (Re)	mg/L	2	<2.0	<2.0	0.00
Rubidium (Rb)	mg/L	0.000005	<0.000005	<0.000005	0.00
Selenium (Se)	mg/L	0.00002	0.000835	0.000954	13.30
Silicon (Si)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silver (Ag)	mg/L	0.05	5.48	5.49	0.18
Sodium (Na)	mg/L	0.000005	<0.000005	<0.000005	0.00
Strontium (Sr)	mg/L	2	3.2	3.4	6.06
Tellurium (Te)	mg/L	0.00005	0.0833	0.0836	0.36
Thallium (Tl)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thorium (Th)	mg/L	0.000002	<0.000004	<0.000004	0.00
Tin (Sn)	mg/L	0.000005	<0.000005	<0.000005	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.0002	<0.0002	<0.0002	0.00
Uranium (U)	mg/L	0.00001	<0.00001	<0.00001	0.00
Vanadium (V)	mg/L	0.000002	0.0000781	0.0000777	0.51
Yttrium (Y)	mg/L	0.00005	<0.00005	<0.000050	0.00
Zinc (Zn)	mg/L	0.000005	<0.000005	<0.000005	0.00
Zirconium (Zr)	mg/L	0.001	<0.001	<0.001	0.00
General Organics					
Benzene	mg/L	0.0005	<0.0005	<0.0005	0.00
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005	0.00
F1(C6-C10)	mg/L	0.1	<0.1	<0.1	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.3 (Cont'd.)

Variable	Unit	Detection Limit	Winter		Relative Percent Difference (%)
			PZ1	Duplicate	
General Organics (Cont'd.)					
F1-BTEX	mg/L	0.1	<0.1	<0.1	0.00
F2 (>C10-C16)	mg/L	0.1	<0.10	<0.10	0.00
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25	0.00
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25	0.00
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0	0.00
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Naphthenic Acids	mg/L	1	<1.0	<1.0	0.00
o-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Phenols (4AAP)	mg/L	0.001	<0.001	<0.0010	0.00
Toluene	mg/L	0.0005	<0.0005	<0.0005	0.00
Xylenes	mg/L	0.00071	<0.00071	<0.00071	0.00
Major Ions					
Bicarbonate (HCO_3)	mg/L	5	205	208	1.45
Calcium (Ca)	mg/L	0.5	47.3	47.8	1.05
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	0.00
Chloride (Cl)	mg/L	0.5	<0.50	0.72	36.07
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	9.12	9.43	3.34
Potassium (K)	mg/L	0.5	1.01	1.02	0.99
Sodium (Na)	mg/L	1	3.6	3.6	0.00
Sulfate (SO_4)	mg/L	0.3	9.85	9.92	0.71
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015	0.00
Nutrients and BOD					
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05	0.00
Biochemical Oxygen Demand	mg/L	2	<2.0	<2.0	0.00
Chlorophyll a	µg/L	0.01	0.271	0.282	3.98
Nitrate (as N)	mg/L	0.02	<0.02	<0.02	0.00
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022	0.00
Nitrite (as N)	mg/L	0.01	<0.01	<0.01	0.00
Phosphorus (P)-Total	mg/L	0.001	0.0109	0.0113	3.60
Phosphorus (P)-Total Dissolved	mg/L	0.001	0.0074	0.0077	3.97
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	<0.2	0.00
Polycyclic Aromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	0.02	0.091	0.067	30.38

\# Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.3 (Cont'd.)

Variable	Unit	Detection Limit	Winter		Relative Percent Difference (%)
			PZ1	Duplicate	
Polycyclic Aromatic Hydrocarbons (Cont'd.)					
2-Methylnaphthalene	µg/L	0.02	0.157	0.115	30.88
Acenaphthene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthylene	µg/L	0.02	<0.02	<0.02	0.00
Acridine	µg/L	4	<4.0	<4.0	0.00
Anthracene	µg/L	0.012	<0.012	<0.012	0.00
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018	0.00
Benzo(a)pyrene	µg/L	0.005	0.0052	0.0068	**26.67**
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Chrysene	µg/L	0.02	<0.02	<0.02	0.00
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02	0.00
Fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Fluorene	µg/L	0.02	<0.02	<0.02	0.00
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02	0.00
Naphthalene	µg/L	0.05	0.342	0.251	30.69
Phenanthrene	µg/L	0.02	<0.02	<0.02	0.00
Pyrene	µg/L	0.02	<0.02	<0.02	0.00
Quinoline	µg/L	0.04	<0.04	<0.04	0.00
Total Metals					
Aluminum (Al)	mg/L	0.003	0.0066	0.0052	**23.73**
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003	0.00
Arsenic (As)	mg/L	0.00005	0.000175	0.000166	5.28
Barium (Ba)	mg/L	0.0001	0.091	0.0812	11.38
Beryllium (Be)	mg/L	0.000005	<0.00001	<0.00001	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.01	0.027	0.023	16.00
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	50.2	48	4.48
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005	0.00
Copper (Cu)	mg/L	0.0005	0.00059	0.00050	16.51
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	0.049	0.044	10.75

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.3 (Cont'd.)

Variable	Unit	Detection Limit	Winter		Relative Percent Difference (%)
			PZ1	Duplicate	
Total Metals (Cont'd.)					
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0004	0.00525	0.00448	15.83
Magnesium (Mg)	mg/L	0.1	10.1	9.7	4.04
Manganese (Mn)	mg/L	0.0002	0.0913	0.0883	3.34
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000071	0.000067	5.80
Molybdenum (Mo)	mg/L	0.00005	0.000165	0.000142	14.98
Nickel (Ni)	mg/L	0.0002	0.00029	0.00026	10.91
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000943	0.000851	10.26
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silicon (Si)	mg/L	0.05	5.82	5.74	1.38
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	3.4	3.2	6.06
Strontium (Sr)	mg/L	0.0002	0.09	0.0869	3.50
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	<0.00020	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000808	0.0000745	8.11
Vanadium (V)	mg/L	0.00005	<0.00005	<0.00005	0.00
Yttrium (Y)	mg/L	0.000005	0.0000066	0.0000053	**21.85**
Zinc (Zn)	mg/L	0.003	<0.003	<0.003	0.00
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.4 Relative percent difference between duplicate water quality samples collected from station PZ1, spring 2018, Fort Hills Oil Sands Project.

Variable	Unit	Detection Limit	Spring		Relative Percent Difference (%)
			PZ1	Duplicate	
Conventional Variables					
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0	0.00
Alkalinity, Total (as $CaCO_3$)	mg/L	2	151	151	0.00
Color, True	C.U.	2	4.5	2.7	**50.00**
Conductivity (EC)	µS/cm	2	296	299	1.01
Dissolved Organic Carbon	mg/L	1	2.7	2.8	3.64
Hardness (as $CaCO_3$)	mg/L	1.3	146	142	2.78
pH	pH	0.1	8.24	8.26	0.24
Total Dissolved Solids	mg/L	10	183	180	1.65
Total Organic Carbon	mg/L	1	3.3	2.8	16.39
Total Suspended Solids	mg/L	3	5.9	4.2	**33.66**
Dissolved Metals					
Aluminum (Al)	mg/L	0.001	<0.001	0.0041	**121.57**
Antimony (Sb)	mg/L	0.00001	<0.00001	<0.00001	0.00
Arsenic (As)	mg/L	0.00005	0.0002	0.000226	12.21
Barium (Ba)	mg/L	0.0001	0.078	0.0789	1.15
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.005	0.0282	0.0275	2.51
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	44.9	47.2	4.99
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	0.000053	5.83
Copper (Cu)	mg/L	0.0002	<0.0002	0.0002	4.88
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	0.166	**138.78**
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0002	0.00515	0.00514	0.19
Magnesium (Mg)	mg/L	0.1	8.20	8.81	7.17
Manganese (Mn)	mg/L	0.0002	0.0171	0.105	143.98
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000027	0.000032	16.95
Molybdenum (Mo)	mg/L	0.00005	0.000159	0.000132	18.56
Nickel (Ni)	mg/L	0.0002	<0.0002	0.00024	18.18

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.4 (Cont'd.)

Variable	Unit	Detection Limit	Spring		Relative Percent Difference (%)
			PZ1	Duplicate	
Dissolved Metals (Cont'd.)					
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000839	0.000843	0.48
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silicon (Si)	mg/L	0.05	4.9100	5.16	4.97
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	4.1	3.8	7.59
Strontium (Sr)	mg/L	0.00005	0.0874	0.0864	1.15
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000002	<0.000002	<0.000002	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000729	0.0000725	0.55
Vanadium (V)	mg/L	0.00005	<0.00005	0.000064	**24.56**
Yttrium (Y)	mg/L	0.000005	<0.000005	0.0000119	**81.66**
Zinc (Zn)	mg/L	0.001	<0.001	0.0018	**57.14**
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00
General Organics					
Benzene	mg/L	0.0005	<0.0005	<0.0005	0.00
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005	0.00
F1(C6-C10)	mg/L	0.1	<0.1	<0.1	0.00
F1-BTEX	mg/L	0.1	<0.1	<0.1	0.00
F2 (C10-C16)	mg/L	0.1	<0.10	<0.10	0.00
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25	0.00
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25	0.00
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0	0.00
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Naphthenic Acids	mg/L	1	<1.0	1.7	**51.85**
o-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001	0.00
Toluene	mg/L	0.0005	<0.0005	<0.0005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.4 (Cont'd.)

Variable	Unit	Detection Limit	Spring		Relative Percent Difference (%)
			PZ1	Duplicate	
Major Ions					
Bicarbonate (HCO_3)	mg/L	5	184	184	0.00
Calcium (Ca)	mg/L	0.5	44.3	43.0	2.98
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	0.00
Chloride (Cl)	mg/L	0.5	0.99	0.99	0.00
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	8.56	8.48	0.94
Potassium (K)	mg/L	0.5	1.1	1.08	1.83
Sodium (Na)	mg/L	1	4.1	4.1	0.00
Sulfate (SO_4)	mg/L	0.3	10.90	10.90	0.00
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015	0.00
Nutrients and BOD					
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05	0.00
Biochemical Oxygen Demand	mg/L	2	2.1	<2.0	4.88
Chlorophyll a	µg/L	0.01	1.77	1.86	4.96
Nitrate (as N)	mg/L	0.02	<0.02	<0.02	0.00
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022	0.00
Nitrite (as N)	mg/L	0.01	<0.01	<0.01	0.00
Phosphorus (P)-Total	mg/L	0.001	0.0272	0.026	4.51
Phosphorus (P)-Total Dissolved	mg/L	0.001	0.0164	0.0159	3.10
Polycyclic Aromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
2-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthylene	µg/L	0.02	<0.02	<0.02	0.00
Acridine	µg/L	4	<4.0	<4.0	0.00
Anthracene	µg/L	0.012	<0.012	<0.012	0.00
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018	0.00
Benzo(a)pyrene	µg/L	0.005	<0.005	<0.005	0.00
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Chrysene	µg/L	0.02	<0.02	<0.02	0.00
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02	0.00
Fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Fluorene	µg/L	0.02	<0.02	<0.02	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.4 (Cont'd.)

Variable	Unit	Detection Limit	Spring		Relative Percent Difference (%)
			PZ1	Duplicate	
Polycyclic Aromatic Hydrocarbons (Cont'd.)					
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02	0.00
Naphthalene	µg/L	0.05	<0.05	<0.05	0.00
Phenanthrene	µg/L	0.02	<0.02	<0.02	0.00
Pyrene	µg/L	0.02	<0.02	<0.02	0.00
Quinoline	µg/L	0.04	<0.04	<0.04	0.00
Total Metals					
Aluminum (Al)	mg/L	0.003	0.0111	0.0173	**43.66**
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003	0.00
Arsenic (As)	mg/L	0.00005	0.000254	0.00024	5.67
Barium (Ba)	mg/L	0.0001	0.0789	0.0743	6.01
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.01	0.036	0.037	2.74
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	47.1	46.5	1.28
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	0.000053	0.000050	5.83
Copper (Cu)	mg/L	0.0005	<0.0005	<0.0005	0.00
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	0.177	0.134	**27.65**
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0004	0.00611	0.00592	3.16
Magnesium (Mg)	mg/L	0.1	8.31	8.04	3.30
Manganese (Mn)	mg/L	0.0002	0.0926	0.0738	22.60
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000061	0.000067	9.38
Molybdenum (Mo)	mg/L	0.00005	0.000188	0.000135	**32.82**
Nickel (Ni)	mg/L	0.0002	0.00031	0.00026	17.54
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.00103	0.00102	0.98
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silicon (Si)	mg/L	0.05	5.11	5.48	6.99

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.4 (Cont'd.)

Variable	Unit	Detection Limit	Spring		Relative Percent Difference (%)
			PZ1	Duplicate	
Total Metals (Cont'd.)					
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	4.4	4.3	2.30
Strontium (Sr)	mg/L	0.0002	0.077	0.075	2.63
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	0.0002	0.00028	0.00029	3.51
Tungsten (W)	mg/L	0.00001	0.000012	0.000010	18.18
Uranium (U)	mg/L	0.000002	0.0000672	0.000068	1.18
Vanadium (V)	mg/L	0.00005	0.000080	0.000078	2.53
Yttrium (Y)	mg/L	0.000005	0.0000163	0.000011	**38.83**
Zinc (Zn)	mg/L	0.003	<0.003	<0.003	0.00
Zirconium (Zr)	mg/L	0.00005	0.000065	<0.00005	**26.09**

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.5 Relative percent difference between duplicate water quality samples collected from station PZ1, summer 2018, Fort Hills Oil Sands Project.

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)
			PZ1	Duplicate	
Conventional Variables					
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0	0.00
Alkalinity, Total (as $CaCO_3$)	mg/L	2	117	117	0.00
Color, True	C.U.	2	5.5	5.9	7.02
Conductivity (EC)	µS/cm	2	218	218	0.00
Dissolved Organic Carbon	mg/L	1	4.8	4.4	8.70
Hardness (as $CaCO_3$)	mg/L	1.3	117	115	1.72
pH	pH	0.1	8.11	8.08	0.37
Total Dissolved Solids	mg/L	10	152	154	1.31
Total Organic Carbon	mg/L	1	4.3	4.6	6.74
Dissolved Metals					
Aluminum (Al)	mg/L	0.001	<0.001	0.0010	0.00
Antimony (Sb)	mg/L	0.00001	0.000012	0.00001	18.18
Arsenic (As)	mg/L	0.00005	0.00022	0.000214	2.76
Barium (Ba)	mg/L	0.0001	0.059	0.0675	13.44
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.005	0.0326	0.0325	0.31
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	32.9	32.6	0.92
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.000050	0.00
Copper (Cu)	mg/L	0.0002	<0.0002	<0.0002	0.00
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	<0.03	0.00
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0002	0.00461	0.00487	5.49
Magnesium (Mg)	mg/L	0.1	8.42	8.06	4.37
Manganese (Mn)	mg/L	0.0002	<0.0002	0.0002	0.00
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000053	0.000028	**61.73**
Molybdenum (Mo)	mg/L	0.00005	0.000125	0.000148	16.85
Nickel (Ni)	mg/L	0.0002	<0.0002	0.00026	**26.09**
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00

\# Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.5 (Cont'd.)

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)
			PZ1	Duplicate	
Dissolved Metals (Cont'd.)					
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000763	0.000789	3.35
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silicon (Si)	mg/L	0.05	4.08	3.82	6.58
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	4.2	4.2	0.00
Strontium (Sr)	mg/L	0.00005	0.0760	0.0788	3.62
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000002	<0.000002	<0.000002	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000606	0.0000660	8.53
Vanadium (V)	mg/L	0.00005	0.000057	0.000055	3.57
Yttrium (Y)	mg/L	0.000005	<0.000005	0.0000050	0.00
Zinc (Zn)	mg/L	0.001	0.0013	0.0067	135.00
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00
General Organics					
Benzene	mg/L	0.0005	<0.0005	<0.0005	0.00
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005	0.00
F1(C6-C10)	mg/L	0.1	<0.1	<0.1	0.00
F1-BTEX	mg/L	0.1	<0.1	<0.1	0.00
F2 (C10-C16)	mg/L	0.1	<0.10	<0.10	0.00
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25	0.00
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25	0.00
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0	0.00
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Naphthenic Acids	mg/L	1	<1.0	1.1	9.52
o-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001	0.00
Toluene	mg/L	0.0005	<0.0005	<0.0005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.5 (Cont'd.)

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)
			PZ1	Duplicate	
Major Ions					
Bicarbonate (HCO_3)	mg/L	5	142	143	0.70
Calcium (Ca)	mg/L	0.5	28.1	30.9	9.49
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	0.00
Chloride (Cl)	mg/L	0.5	0.50	0.70	**33.33**
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	8.82	9.57	8.16
Potassium (K)	mg/L	0.5	0.78	0.72	8.00
Sodium (Na)	mg/L	1	4.1	4.2	2.41
Sulfate (SO_4)	mg/L	0.3	11.10	11.00	0.90
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015	0.00
Nutrients and BOD					
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05	0.00
Biochemical Oxygen Demand	mg/L	2	2.9	2.7	7.14
Chlorophyll a	µg/L	0.01	0.771	0.813	5.30
Nitrate (as N)	mg/L	0.02	0.038	<0.020	**62.07**
Nitrate and Nitrite (as N)	mg/L	0.022	0.038	<0.022	**53.33**
Nitrite (as N)	mg/L	0.01	<0.01	<0.01	0.00
Phosphorus (P)-Total	mg/L	0.001	0.0052	0.0067	25.21
Phosphorus (P)-Total Dissolved	mg/L	0.001	0.0044	0.0079	**56.91**
Total Kjeldahl Nitrogen	mg/L	0.2	0.68	0.5	**28.57**
Polycyclic Aromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
2-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthylene	µg/L	0.02	<0.02	<0.02	0.00
Acridine	µg/L	4	<4.0	<4.0	0.00
Anthracene	µg/L	0.012	<0.012	<0.012	0.00
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018	0.00
Benzo(a)pyrene	µg/L	0.005	<0.005	<0.005	0.00
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Chrysene	µg/L	0.02	<0.02	<0.02	0.00
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02	0.00
Fluoranthene	µg/L	0.02	<0.02	<0.02	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.5 (Cont'd.)

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)
			PZ1	Duplicate	
Polycyclic Aromatic Hydrocarbons (Cont'd.)					
Fluorene	µg/L	0.02	<0.02	<0.02	0.00
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02	0.00
Naphthalene	µg/L	0.05	<0.05	<0.05	0.00
Phenanthrene	µg/L	0.02	<0.02	<0.02	0.00
Pyrene	µg/L	0.02	<0.02	<0.02	0.00
Quinoline	µg/L	0.04	<0.04	<0.04	0.00
Total Metals					
Aluminum (Al)	mg/L	0.003	0.0044	0.0051	14.74
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003	0.00
Arsenic (As)	mg/L	0.00005	0.000208	0.000202	2.93
Barium (Ba)	mg/L	0.0001	0.0654	0.066	0.91
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.01	0.034	0.031	9.23
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	32.2	34.4	6.61
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005	0.00
Copper (Cu)	mg/L	0.0005	<0.0005	<0.0005	0.00
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	<0.03	0.00
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0004	0.00458	0.00477	4.06
Magnesium (Mg)	mg/L	0.1	8.1	8.29	2.32
Manganese (Mn)	mg/L	0.0002	0.00669	0.00707	5.52
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000058	0.00004	**36.73**
Molybdenum (Mo)	mg/L	0.00005	0.000132	0.000138	4.44
Nickel (Ni)	mg/L	0.0002	0.00029	0.00029	0.00
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000787	0.00071	10.29
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00

\# Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.5 (Cont'd.)

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)
			PZ1	Duplicate	
Total Metals (Cont'd.)					
Silicon (Si)	mg/L	0.05	3.87	3.87	0.00
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	5.2	5.3	1.90
Strontium (Sr)	mg/L	0.0002	0.0753	0.0704	6.73
Tellurium (Te)	mg/L	0.00001	0.000016	0.000014	13.33
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000651	0.0000664	1.98
Vanadium (V)	mg/L	0.00005	0.000076	0.000064	17.14
Yttrium (Y)	mg/L	0.000005	0.0000066	<0.00001	**27.59**
Zinc (Zn)	mg/L	0.003	<0.003	0.0098	**106.25**
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

(shaded) Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.6 Relative percent difference between duplicate water quality samples collected from station PZ1, fall 2018, Fort Hills Oil Sands Project.

Variable	Unit	Detection Limit	Fall		Relative Percent Difference (%)
			PZ1	Duplicate	
Conventional Variables					
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2.0	<2.0	0.00
Alkalinity, Total (as $CaCO_3$)	mg/L	2	119	121	1.67
Color, True	C.U.	2	5.1	5.2	1.94
Conductivity (EC)	µS/cm	2	261	260	0.38
Dissolved Organic Carbon	mg/L	1	5.1	5.2	1.94
Hardness (as $CaCO_3$)	mg/L	1.3	118	116	1.71
pH	pH	0.1	8.24	8.26	0.24
Total Dissolved Solids	mg/L	10	146	143	2.08
Total Organic Carbon	mg/L	1	4.9	4.9	0.00
Total Suspended Solids	mg/L	3	<3.0	<3.0	0.00
Dissolved Metals					
Aluminum (Al)	mg/L	0.001	<0.001	0.001	0.00
Antimony (Sb)	mg/L	0.00001	0.000018	0.000018	0.00
Arsenic (As)	mg/L	0.00005	0.000199	0.000199	0.00
Barium (Ba)	mg/L	0.0001	0.063	0.061	3.23
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.005	0.0311	0.0304	2.28
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	31.6	31.5	0.32
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.000050	0.00
Copper (Cu)	mg/L	0.0002	0.00023	<0.0003	**26.42**
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	<0.03	0.00
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005	0.00
Lithium (Li)	mg/L	0.0002	0.00539	0.00531	1.50
Magnesium (Mg)	mg/L	0.1	9.48	9.09	4.20
Manganese (Mn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000038	0.000037	2.67
Molybdenum (Mo)	mg/L	0.00005	0.000132	0.000129	2.30
Nickel (Ni)	mg/L	0.0002	<0.00022	0.00023	4.44

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.6 (Cont'd.)

Variable	Unit	Detection Limit	Fall		Relative Percent Difference (%)
			PZ1	Duplicate	
Dissolved Metals (Cont'd.)					
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000851	0.000827	2.86
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00
Silicon (Si)	mg/L	0.05	3.17	2.93	7.87
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	4.3	4.3	0.00
Strontium (Sr)	mg/L	0.00005	0.0796	0.0814	2.24
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000002	<0.000002	<0.000002	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000769	0.0000721	6.44
Vanadium (V)	mg/L	0.00005	<0.00005	0.000050	0.00
Yttrium (Y)	mg/L	0.000005	<0.000005	<0.000005	0.00
Zinc (Zn)	mg/L	0.001	0.0013	0.0012	8.00
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00
General Organics					
Benzene	mg/L	0.0005	<0.0005	<0.0005	0.00
Ethylbenzene	mg/L	0.0005	<0.0005	<0.0005	0.00
F1(C6-C10)	mg/L	0.1	<0.1	<0.1	0.00
F1-BTEX	mg/L	0.1	<0.1	<0.1	0.00
F2 (C10-C16)	mg/L	0.1	<0.10	<0.10	0.00
F3 (C16-C34)	mg/L	0.25	<0.25	<0.25	0.00
F4 (C34-C50)	mg/L	0.25	<0.25	<0.25	0.00
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1.0	<1.0	0.00
Oil & Grease-(IR)	mg/L	1	<1.0	<1.0	0.00
m+p-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Naphthenic Acids	mg/L	1	1.0	1.0	0.00
o-Xylene	mg/L	0.0005	<0.0005	<0.0005	0.00
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001	0.00
Toluene	mg/L	0.0005	<0.0005	<0.0005	0.00
Xylenes	mg/L	0.00071	<0.00071	<0.00071	0.00

\# Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.6 (Cont'd.)

Variable	Unit	Detection Limit	Fall		Relative Percent Difference (%)
			PZ1	Duplicate	
Major Ions					
Bicarbonate (HCO_3)	mg/L	5	146	147	0.68
Calcium (Ca)	mg/L	0.5	33.5	33.7	0.60
Carbonate (CO_3)	mg/L	5	<5.0	<5.0	0.00
Chloride (Cl)	mg/L	0.5	0.58	0.58	0.00
Hydroxide (OH)	mg/L	5	<5.0	<5.0	0.00
Magnesium (Mg)	mg/L	0.1	10.6	10.7	0.94
Potassium (K)	mg/L	0.5	0.99	1.01	2.00
Sodium (Na)	mg/L	1	4.5	4.5	0.00
Sulfate (SO_4)	mg/L	0.3	10.3	10.20	0.98
Sulphide (as S)	mg/L	0.0015	<0.0015	<0.0015	0.00
Nutrients and BOD					
Ammonia, Total (as N)	mg/L	0.05	<0.05	0.057	13.08
Biochemical Oxygen Demand	mg/L	2	<2.0	<2.0	0.00
Chlorophyll a	µg/L	0.01	0.481	0.391	20.64
Nitrate (as N)	mg/L	0.02	<0.02	<0.02	0.00
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022	0.00
Nitrite (as N)	mg/L	0.01	<0.01	<0.01	0.00
Phosphorus (P)-Total	mg/L	0.001	0.021	0.0203	3.39
Phosphorus (P)-Total Dissolved	mg/L	0.001	0.0168	0.016	4.88
Total Kjeldahl Nitrogen	mg/L	0.2	<0.20	0.24	18.18
Polycyclic Aromatic Hydrocarbons					
1-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
2-Methylnaphthalene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthene	µg/L	0.02	<0.02	<0.02	0.00
Acenaphthylene	µg/L	0.02	<0.02	<0.02	0.00
Acridine	µg/L	4	<4.0	<4.0	0.00
Anthracene	µg/L	0.012	<0.012	<0.012	0.00
Benzo(a)anthracene	µg/L	0.018	<0.018	<0.018	0.00
Benzo(a)pyrene	µg/L	0.005	<0.005	<0.005	0.00
Benzo(b)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(g,h,i)perylene	µg/L	0.02	<0.02	<0.02	0.00
Benzo(k)fluoranthene	µg/L	0.02	<0.02	<0.02	0.00
Chrysene	µg/L	0.02	<0.02	<0.02	0.00
Dibenzo(ah)anthracene	µg/L	0.02	<0.02	<0.02	0.00
Fluoranthene	µg/L	0.02	<0.02	<0.02	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.6 (Cont'd.)

Variable	Unit	Detection Limit	Fall		Relative Percent Difference (%)
			PZ1	Duplicate	
Polycyclic Aromatic Hydrocarbons (Cont'd.)					
Fluorene	µg/L	0.02	<0.02	<0.02	0.00
Indeno(1,2,3-cd)pyrene	µg/L	0.02	<0.02	<0.02	0.00
Naphthalene	µg/L	0.05	<0.05	<0.05	0.00
Phenanthrene	µg/L	0.02	<0.02	<0.02	0.00
Pyrene	µg/L	0.02	<0.02	<0.02	0.00
Quinoline	µg/L	0.04	<0.04	<0.04	0.00
Total Metals					
Aluminum (Al)	mg/L	0.003	0.0056	0.0052	7.41
Antimony (Sb)	mg/L	0.00003	<0.00003	<0.00003	0.00
Arsenic (As)	mg/L	0.00005	0.0002	0.000215	7.23
Barium (Ba)	mg/L	0.0001	0.0617	0.0618	0.16
Beryllium (Be)	mg/L	0.000005	<0.000005	<0.000005	0.00
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005	0.00
Boron (B)	mg/L	0.01	0.031	0.032	3.17
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005	0.00
Calcium (Ca)	mg/L	0.05	29.4	29.2	0.68
Cesium (Cs)	mg/L	0.000005	<0.000005	<0.000005	0.00
Chromium (Cr)	mg/L	0.0005	<0.0005	<0.0005	0.00
Cobalt (Co)	mg/L	0.00005	<0.00005	<0.00005	0.00
Copper (Cu)	mg/L	0.0005	0.00169	<0.0005	**108.68**
Gallium (Ga)	mg/L	0.00005	<0.00005	<0.00005	0.00
Iron (Fe)	mg/L	0.03	<0.03	<0.03	0.00
Lead (Pb)	mg/L	0.00005	0.000064	<0.00005	**24.56**
Lithium (Li)	mg/L	0.0004	0.00519	0.00529	1.91
Magnesium (Mg)	mg/L	0.1	8.22	8.28	0.73
Manganese (Mn)	mg/L	0.0002	0.00382	0.00388	1.56
Mercury (Hg)	µg/L	0.0005	<0.0005	<0.0005	0.00
Methyl Mercury	µg/L	0.00005	0.000038	0.000037	2.67
Molybdenum (Mo)	mg/L	0.00005	0.00014	0.000151	7.56
Nickel (Ni)	mg/L	0.0002	0.00049	0.00034	**36.14**
Phosphorus (P)	mg/L	0.3	<0.3	<0.3	0.00
Potassium (K)	mg/L	2	<2.0	<2.0	0.00
Rhenium (Re)	mg/L	0.000005	<0.000005	<0.000005	0.00
Rubidium (Rb)	mg/L	0.00002	0.000821	0.000796	3.09
Selenium (Se)	mg/L	0.0002	<0.0002	<0.0002	0.00

\# Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

\# Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.6 (Cont'd.)

Variable	Unit	Detection Limit	Fall		Relative Percent Difference (%)
			PZ1	Duplicate	
Total Metals (Cont'd.)					
Silicon (Si)	mg/L	0.05	2.92	2.99	2.37
Silver (Ag)	mg/L	0.000005	<0.000005	<0.000005	0.00
Sodium (Na)	mg/L	2	4	4	0.00
Strontium (Sr)	mg/L	0.0002	0.0739	0.0741	0.27
Tellurium (Te)	mg/L	0.00001	<0.00001	<0.00001	0.00
Thallium (Tl)	mg/L	0.000005	<0.000005	<0.000005	0.00
Thorium (Th)	mg/L	0.000005	<0.000005	<0.000005	0.00
Tin (Sn)	mg/L	0.0002	<0.0002	<0.0002	0.00
Titanium (Ti)	mg/L	0.0002	<0.0002	<0.0002	0.00
Tungsten (W)	mg/L	0.00001	<0.00001	<0.00001	0.00
Uranium (U)	mg/L	0.000002	0.0000675	0.0000658	2.55
Vanadium (V)	mg/L	0.00005	0.000059	0.000063	6.56
Yttrium (Y)	mg/L	0.000005	0.0000076	0.0000053	**35.66**
Zinc (Zn)	mg/L	0.003	<0.003	<0.003	0.00
Zirconium (Zr)	mg/L	0.00005	<0.00005	<0.00005	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

A6.2.2 Sediment Quality

One duplicate sample was collected at station PZ1 in fall 2018. No analytes differed by more than 20% between duplicate samples (Table A6.7). In contrast to 2017, relative percent difference between duplicate samples in sediment of the NNLL (2018) indicate that there is homogeneity in sediment.

Internal QA/QC results from ALS Laboratories did not indicate obvious contamination issues; therefore, sediment quality results from 2018 were considered valid and accurate.

Table A6.7 Relative percent difference between duplicate sediment quality samples collected from No Net Loss Lake, Fort Hills Oil Sands Project, fall 2018.

Analyte	Units	Detection Limit		Station		Relative Percent Difference (%)
		PZ1	Duplicate	PZ1	Duplicate	
Physical Properties						
Clay	%	1	1	14	14	0.00
Moisture	%	0.5	0.5	61.6	61.6	0.00
Sand	%	1	1	41	40	2.47
Silt	%	1	1	45	46	2.20
Inorganic Carbon	%	0.05	0.05	0.52	0.59	12.85
Total Carbon by Combustion	%	0.05	0.05	8.28	9.21	10.63
Total Organic Carbon	%	0.05	0.05	7.76	8.62	10.50
$CaCO_3$ Equivalent	%	0.4	0.4	4.3	4.9	13.04
Total Metals						
Aluminum (Al)	mg/kg	50	50	8880	8290	6.87
Antimony (Sb)	mg/kg	0.1	0.1	0.19	0.18	5.41
Arsenic (As)	mg/kg	0.1	0.1	4.56	4.33	5.17
Barium (Ba)	mg/kg	0.5	0.5	222	206	7.48
Beryllium (Be)	mg/kg	0.1	0.1	0.53	0.51	3.85
Bismuth (Bi)	mg/kg	0.2	0.2	<0.20	<0.20	0.00
Boron (B)	mg/kg	5	5	25.1	24.6	2.01
Cadmium (Cd)	mg/kg	0.02	0.02	0.148	0.131	12.19
Calcium (Ca)	mg/kg	50	50	22900	19800	14.52
Chromium (Cr)	mg/kg	0.5	0.5	15.2	14.8	2.67
Cobalt (Co)	mg/kg	0.1	0.1	6.83	6.19	9.83
Copper (Cu)	mg/kg	0.5	0.5	11.5	10.8	6.28
Iron (Fe)	mg/kg	50	50	22500	21100	6.42
Lead (Pb)	mg/kg	0.5	0.5	7.26	6.58	9.83
Lithium (Li)	mg/kg	2	2	11	9.9	10.53
Magnesium (Mg)	mg/kg	20	20	4460	4000	10.87
Manganese (Mn)	mg/kg	1	1	548	528	3.72
Mercury (Hg)	mg/kg	0.005	0.005	0.0301	0.0321	6.43
Molybdenum (Mo)	mg/kg	0.1	0.1	0.56	0.52	7.41

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.7 (Cont'd.)

Analyte	Units	Detection Limit		Station		Relative Percent Difference (%)
		PZ1	Duplicate	PZ1	Duplicate	
Total Metals (Cont'd.)						
Nickel (Ni)	mg/kg	0.5	0.5	17.8	16.6	6.98
Phosphorus (P)	mg/kg	50	50	539	482	11.17
Potassium (K)	mg/kg	100	100	1370	1220	11.58
Selenium (Se)	mg/kg	0.2	0.2	0.43	0.41	4.76
Silver (Ag)	mg/kg	0.1	0.1	<0.10	<0.10	0.00
Sodium (Na)	mg/kg	50	50	136	125	8.43
Strontium (Sr)	mg/kg	0.5	0.5	84.1	74.7	11.84
Thallium (Tl)	mg/kg	0.05	0.05	0.156	0.141	10.10
Tin (Sn)	mg/kg	2	2	<2.0	<2.0	0.00
Titanium (Ti)	mg/kg	1	1	37.2	36.9	0.81
Uranium (U)	mg/kg	0.05	0.05	0.697	0.606	13.97
Vanadium (V)	mg/kg	0.2	0.2	25.6	24.6	3.98
Zinc (Zn)	mg/kg	2	2	43.1	38.4	11.53
Zirconium (Zr)	mg/kg	1	1	7.5	7	6.90
Hydrocarbons and Organic Compounds						
Benzene	mg/kg	0.017	0.017	<0.017	<0.015	12.50
Ethylbenzene	mg/kg	0.050	0.050	<0.050	<0.044	12.77
F1 (C6-C10)	mg/kg	33	33	<33	<29	12.90
F1-BTEX	mg/kg	33	33	<33	<29	12.90
F2 (C10-C16)	mg/kg	25	25	34	34	0.00
F3 (C16-C34)	mg/kg	50	50	644	625	2.99
F4 (C34-C50)	mg/kg	50	50	499	483	3.26
F4G-SG (GHH-Silica)	mg/kg	500	500	-	-	-
o-Xylene	mg/kg	0.017	0.1455	<0.17	<0.15	12.50
Toluene	mg/kg	0.04	0.04074	<0.046	<0.041	11.49
Total Hydrocarbons (C6-C50)	mg/kg	50	50	1180	1140	3.45
Xylenes	mg/kg	0.21	0.21	<0.23	<0.21	9.09
m+p-Xylene	mg/kg	0.17	0.1455	<0.17	<0.15	12.50
Polycyclic Aromatic Hydrocarbons						
2-Methylnaphthalene	mg/kg	0.005	0.005	<0.01	<0.01	0.00
Acenaphthene	mg/kg	0.002	0.003	<0.005	<0.005	0.00
Acenaphthylene	mg/kg	0.002	0.002	<0.005	<0.005	0.00
Anthracene	mg/kg	0.004	0.004	<0.004	<0.004	0.00
Benz(a)anthracene	mg/kg	0.005	0.005	<0.010	<0.010	0.00
Benzo(a)pyrene	mg/kg	0.002	0.002	<0.010	<0.010	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

Table A6.7 (Cont'd.)

Analyte	Units	Detection Limit		Station		Relative Percent Difference (%)
		PZ1	Duplicate	PZ1	Duplicate	
Total Metals (Cont'd.)						
Chrysene	mg/kg	0.005	0.005	0.015	0.018	18.18
Dibenz(a,h)anthracene	mg/kg	0.005	0.005	<0.005	<0.005	0.00
Fluoranthene	mg/kg	0.005	0.005	<0.010	<0.010	0.00
Fluorene	mg/kg	0.005	0.005	<0.010	<0.010	0.00
Naphthalene	mg/kg	0.005	0.005	<0.010	<0.010	0.00
Phenanthrene	mg/kg	0.005	0.005	<0.010	<0.010	0.00
Pyrene	mg/kg	0.005	0.005	<0.010	<0.010	0.00

Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.

Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.

A6.2.3 Benthic Invertebrate Communities

Mean sorting efficiency of benthic invertebrates was 97% for benthic samples collected from the NNLL (Table A6.8). Based on the criterion of 90% sorting efficiency, these results were considered acceptable and additional QC activities were not required.

Table A6.8 Results of the sorting efficiency of benthic invertebrate samples collected from the No Net Loss Lake, Fort Hills Oil Sands Project, fall 2018.

Sample Station	% Sorting Efficiency
PZ1-2	[1-(18/(635+18))]*100 = 97.2
LZ3-1	[1-(43/(1649+43))]*100 = 97.5
Mean sorting efficiency (%)	97.4%

Sorting efficiency = [1-(# in QA/AC re-sort / (# sorted originally + # QA/QC resort))]* 100.

Appendix A7

Fort Creek Update

GOLDER

TECHNICAL MEMORANDUM

DATE April 15, 2019 **Project No.** 18101477

TO Michael Robinson, Regulatory Specialist
Suncor Energy Inc.

CC Carly Merkosky, Michael Day, Blake Smith

FROM Chris Bjornson, Senior Fisheries Biologist **EMAIL chris_bjornson@golder.com**

APPENDIX A7: UPDATE TO FORT CREEK FISH HABITAT MODELLING – FORT HILLS OIL SANDS PROJECT

1.0 INTRODUCTION

As part of the approvals process for the Fort Hills Oil Sands Project (Fort Hills) a Conceptual No Net Loss Plan (Golder 2002) and No Net Loss Lake (NNLL) Development Plan (Golder 2006) were prepared to describe how compensation would be provided for the Harmful Alteration, Disruption or Destruction (HADD) of productive fish habitats resulting from development of the project. Affected habitats included Fort Creek, Susan Lake and the Susan Lake Outlet Channel. A *Fisheries Act* Section 35(2) Authorization was subsequently issued by Fisheries and Oceans Canada (DFO; Authorization AB00-517-2013) that authorized the HADD for Fort Creek only (i.e., initial habitat losses associated with Fort Hills) and the construction of the planned NNLL. As part of the HADD for Fort Creek, a temporary fish barrier was installed in December 2006, 455 m upstream of the confluence with the Athabasca River, to deny upstream fish movement until upstream areas were dewatered. The sandbag-constructed temporary barrier has not been maintained or monitored post-installation and is no longer functioning to deny fish access upstream. Therefore, fish have access to the habitat upstream as Fort Creek has remained largely unaltered upstream of the barrier. The NNLL Development Plan (Golder 2006) specified that application for authorization of the HADD of Susan Lake and its outlet channel would be made at a later date and that the compensation provided by the development of the NNLL was also expected to compensate for all of the HADD in the Susan Lake watershed.

This technical memo provides an evaluation of current conditions in lower Fort Creek and updates the fish habitat suitability modelling used to quantify the productivity of the habitats. This memorandum provides the following updates:

1) An assessment of the current status and productivity of fish habitats in lower Fort Creek in relation to alterations that have occurred to date in the upper watershed.

2) Update to the Fort Creek fish habitat suitability modelling using supplemental baseline and current data for the creek and the revised habitat suitability index (HSI) models for the oil sands region (Golder 2008a).

2.0 SUPPLEMENTAL FIELD SURVEYS OF FORT CREEK

The following is a summary of the fall 2017 and fall 2018 fish and fish habitat assessments of lower Fort Creek. The purpose of the field surveys was to collect current data describing fish habitat characteristics and fish use of lower Fort Creek for comparison to the results of previous surveys. The methods used for the 2017/2018 surveys were consistent with the previous fish and fish habitat surveys of lower Fort Creek. Previous surveys included:

- 1996 fisheries investigation conducted for the Syncrude Aurora Mine (Golder 1996);
- 1999 aquatics baseline program for the Fort Hills Oil Sands Project (Golder 2000);
- 2000/2001 surveys conducted for the Fort Hills Environmental Baseline Study (TrueNorth 2001);
- 2006 and 2007 Fort Creek Fish and Fish Habitat Monitoring surveys (Golder 2008b); and
- Regional Aquatics Monitoring surveys – monitoring conducted by the Regional Aquatics Monitoring Program (RAMP 2012, 2013, 2014) and the Alberta Environment Monitoring, Evaluation and Reporting Agency (AEMERA 2015).

2017/2018 Survey Locations

Two survey locations were selected on lower Fort Creek for inclusion in both the 2017 and 2018 fish and fish habitat surveys (Table 1), based on their accessibility and continuous sampling history over the various years in which surveys were conducted.

1. Downstream Location: the lower-most section of Fort Creek extending for 300 m upstream from the creek mouth, at the confluence with the Athabasca River.

2. Upstream Location: the 300 m long section of Fort Creek located immediately downstream of the Fort Chipewyan road (Highway 63) crossing.

Table 1: Lower Fort Creek Survey Locations and Dates

Location	UTM Coordinates (NAD 83, Zone 12V)				Survey Dates	
	Downstream Boundary		Upstream Boundary			
	Easting	Northing	Easting	Northing	2017	2018
Downstream (creek mouth)	461525	6363110	461788	6363105	12 October	6 October
Upstream (near road crossing)	462363	6363565	462630	6363545	19 October	7 October

Note: UTM = Universal Transverse Mercator Grid; NAD = North American Datum

2017/2018 Survey Methods

The fish and fish habitat survey methods employed in 2017/2018 were similar to the survey methods used for the previous surveys of lower Fort Creek (Golder 1996, 2000; TrueNorth 2001; Golder 2008b; RAMP 2012, 2013, 2014, AEMERA 2015). During the 2017/2018 assessments, habitat data were collected for a 300 m length of watercourse channel at each of the two Fort Creek survey locations. Each section was divided longitudinally into distinct channel units representing different classes of key habitat types (i.e., riffle, run pool), to provide the composition and extent of each channel unit type. Key information collected from each individual channel unit included channel unit type, channel (bankfull) width, instream cover types and percent cover for fish, overhead cover types and percent availability, substrate particle size distribution, discharge, basic water quality, identification of any barriers or impedances to fish passage, and representative photographs.

During the 2017/2018 assessments, fish sampling was conducted at the two Fort Creek survey locations by backpack electrofishing and minnow trapping. A single pass electrofishing effort was conducted at each site, sampling across the entire wetted width of the channel. Minnow trapping was conducted at each survey location in local low-velocity areas with instream cover.

Sampling effort was used to calculate catch-per-unit-effort (CPUE) values for each survey location and sampling method – electrofishing CPUE was expressed as number of fish captured per 100 seconds of active electrofishing, and minnow trapping CPUE was expressed as number of fish captured per trap-hour. CPUE values allowed comparison of fish abundance (as represented by catch rate) between sampling sites or sampling years.

Comparison of 2017/2018 Results to Previous Surveys

The results for the fish and fish habitat assessment of the two survey locations in lower Fort Creek were compared to previous survey data. For the downstream location, the same location was surveyed in all years. For the upstream location, there was some variability in the exact section of creek surveyed among the years, but all surveys were conducted in the same general area.

Fish Habitat

For the Fort Creek downstream location, the channel unit composition has varied to some extent over the surveyed years. The proportion of habitat consisting of shallow (Class 3) versus deeper (Class 2) runs has varied, as has the proportion of impoundment pools. This variability is likely explained by the variability in flow levels for the different surveys and the presence/absence of beaver dams. The proportion of deeper Class 2 runs was highest in 2000 when the habitat survey was conducted in the spring rather than the summer or fall as in the other years, suggesting higher water levels would account for the higher proportion of deeper runs. The lack of deeper Class 2 runs in 2017/2018 is likely due to the surveys being conducted in October, when flow levels were the lowest of any of the surveys. The observation from the 2017/2018 surveys that beaver dams located in the survey area were all breached explains the lack of impoundment pools in 2017/2018, and suggest that relatively high flows occurred in the creek sometime between the 2000 and 2017/2018 surveys that would have breached the dams, such as the recent high flow event that resulted in flooding in the region. This possible flushing of the watercourse by a recent high flow event is supported by the lower level of woody debris present in the creek in 2017/2018 compared to previous years.

The channel dimensions (widths) were similar among most years at the downstream location, but were higher in 1996 relative to the other surveys. Similarity between channel widths in 2017 and those recorded in 1999 and 2000 shows there is no evidence of reduced or increased channel size. The results also show no reduction in bank stability over time as indicated by similar slope stability observed between the surveys completed in 1996

and 2018.

The substrate in the downstream location was heavily dominated by fine sediments in all survey years. Although some rocky material was recorded in 1999, the potential for the downstream section of lower Fort Creek to support spawning by large-bodied fish from the Athabasca River that prefer swift flowing rocky habitat was described in all years as very low, due to the small proportion of rocky material and its high degree of embeddedness in fine sediment.

Habitat characteristics at the Fort Creek upstream location have also showed some variability among survey years. As with the downstream location, the variability may be explained by differences in flow levels between surveys, and possible high flow event(s) occurring prior to the 2017/2018 surveys. In all years the composition of channel units was a mix of Class 3 runs and riffles. The highest proportion of runs occurred in 2000 and is likely due to this survey occurring during the high water level period in the spring, relative to the summer or fall period for the other surveys. A small amount of impoundment pool habitat was recorded in 1996 and 1999, but not in 2000 or 2017/2018, indicating a lack of beaver dams (or beaver dam integrity) in more recent years.

The average channel width in the upstream location has varied. It was highest in 2017, which was also the only year that the channel width in the upstream location was higher than in the downstream location. The data suggests that the channel size at the upstream location has increased and become more similar to the downstream location than in previous years. There is no evidence of recent channel destabilization and the bank stability rating has not changed, although there is a higher percentage of undercut bank in the area. This increase in undercut bank may be due to a recent high flow event, as suggested by the reduction in woody debris at this location in 2017/2018. The recent surveys also show there has been a recent increase in rocky substrates observed in the upstream location, which may also be indicative of a recent high flow event that may have facilitated flushing of some fine sediment from the creek section.

Fish Populations

A total of 14 fish species have been recorded in lower Fort Creek for all survey years and locations combined, consisting of 2 sport fish species (Burbot, Northern Pike), 2 sucker species (Longnose and White Sucker) and 10 forage fish species (Table 2). All 14 species have been recorded at the downstream location, while 11 of these species were also recorded at the upstream location – consisting of Burbot, both sucker species and 8 forage fish species. The somewhat larger number of species at the downstream location is explained by its proximity to fish populations in the Athabasca River and to limited upstream fish passage characteristics in the creek in some years due to the number of beaver dams and cascades recorded, or to low water depths. Species more typically associated with the Athabasca River (such as Northern Pike, Emerald and Spottail Shiner) have only been recorded at the downstream station.

The number of fish species captured in lower Fort Creek in any given year has been highly variable. At the downstream location the number of species ranged from only two species in 1999 to nine species in 2012, with an average of 4.9 species per survey. The four species recorded in 2017, although about average relative to all years, is actually considered relatively high, since the 2017 survey was conducted late in the year (October) during a period of regional low flows (the lowest water level of any survey) compared to other survey years. In addition, both large-bodied and small-bodied species were present in fall 2017. Again, the variability in species presence at the downstream location is due to the proximity to the Athabasca River and occasional use of the Fort Creek by some species. The two species captured in 2018 was low but within the historical range.

At the upstream location, the number of species captured in the various survey years ranged from two species to

four species, with an average of 2.8 species per survey. The species recorded in the recent surveys were near average (two species) in 2017 and above average (four species) in 2018. The number of species recorded in both 2017 and 2018 are considered relatively high, since the surveys were conducted late in the year (October) during the period of low flows. In addition, both large-bodied and small-bodied species were present in fall 2018.

Fish abundance (as measured by CPUE) at the downstream location for all survey years prior to 2017/2018 ranged from 0 fish/100 sec to 13.0 fish/100 sec of electrofishing (average of 4.1 fish/100 sec), and from 0 fish/trap-hr to 0.25 fish/trap-hr for minnow trapping (average of 0.13 fish/trap-hr). The electrofishing CPUE was above average in 2017 (6.4 fish/100s) and below average in 2018 (1.8 fish/100 sec), while the minnow trapping CPUE was also above average in 2017 (0.25 fish/trap-hr) and below average in 2018 (0 fish/trap-hr).

Fish abundance at the upstream location for all survey years prior to 2017/2018 ranged from 0.14 fish/100 sec to 8.2 fish/100 sec of electrofishing (average of 2.1 fish/100 sec), and from 0 fish/trap-hr to 0.3 fish/trap-hr for minnow trapping (average of 0.13 fish/trap-hr). The electrofishing CPUE was below average in 2017 (0.3 fish/100s) and near average in 2018 (1.7 fish/100 sec), while the minnow trapping CPUE was also below average in 2017 (0 fish/trap-hr) and near average in 2018 (0.2 fish/trap-hr).

Summary

The results of the fall 2017 and fall 2018 fish and fish habitat surveys indicate that there have been no observable change in habitat conditions or fish use that indicate a change in the ability of lower Fort Creek to provide productive fish habitats and to continue to provide the creek's natural level of support for fish populations in the Athabasca River. Differences in recorded habitat parameters among survey years are likely due to differences in flows and water levels associated with the various survey seasons and years, with indications in both survey locations that a high flow event occurred between the 2017 survey and the previous surveys. Overall fish species presence in lower Fort Creek has been variable and remains so, with sport fish and sucker only occasionally present. Despite the 2017 survey being conducted in October and during a period of low water levels, species diversity and abundance was at typical levels.

Update of Fish Habitat Suitability Modelling

Fish HSI modelling is a method for providing a measure of fish habitat quality as part of the quantification of fish habitat productivity. HSI values are combined with measures of habitat quantity (i.e., surface area) to provide an estimate of overall habitat productivity, represented by Habitat Units (HUs = HSI x area [m^2]). HSI modelling and HU quantifications were completed in the Fort Hills Conceptual No Net Loss Plan (Golder 2002) for habitat losses expected in Fort Creek. At that time, the plan was to provide compensation for all losses of habitat productivity in affected habitats at a ration of 2:1 (2 HU gains to each HU loss).

The previous HSI modelling employed the 2005 versions of the fish HSI models (Golder 2005). The updated HSI modelling was conducted using the current version of the models, which were updated in 2008 (Golder 2008a). In addition to using the updated models, all fish and fish habitat data available since the previous modelling efforts were compiled and used in the update. Available fish and fish habitat data consisted of the following information:

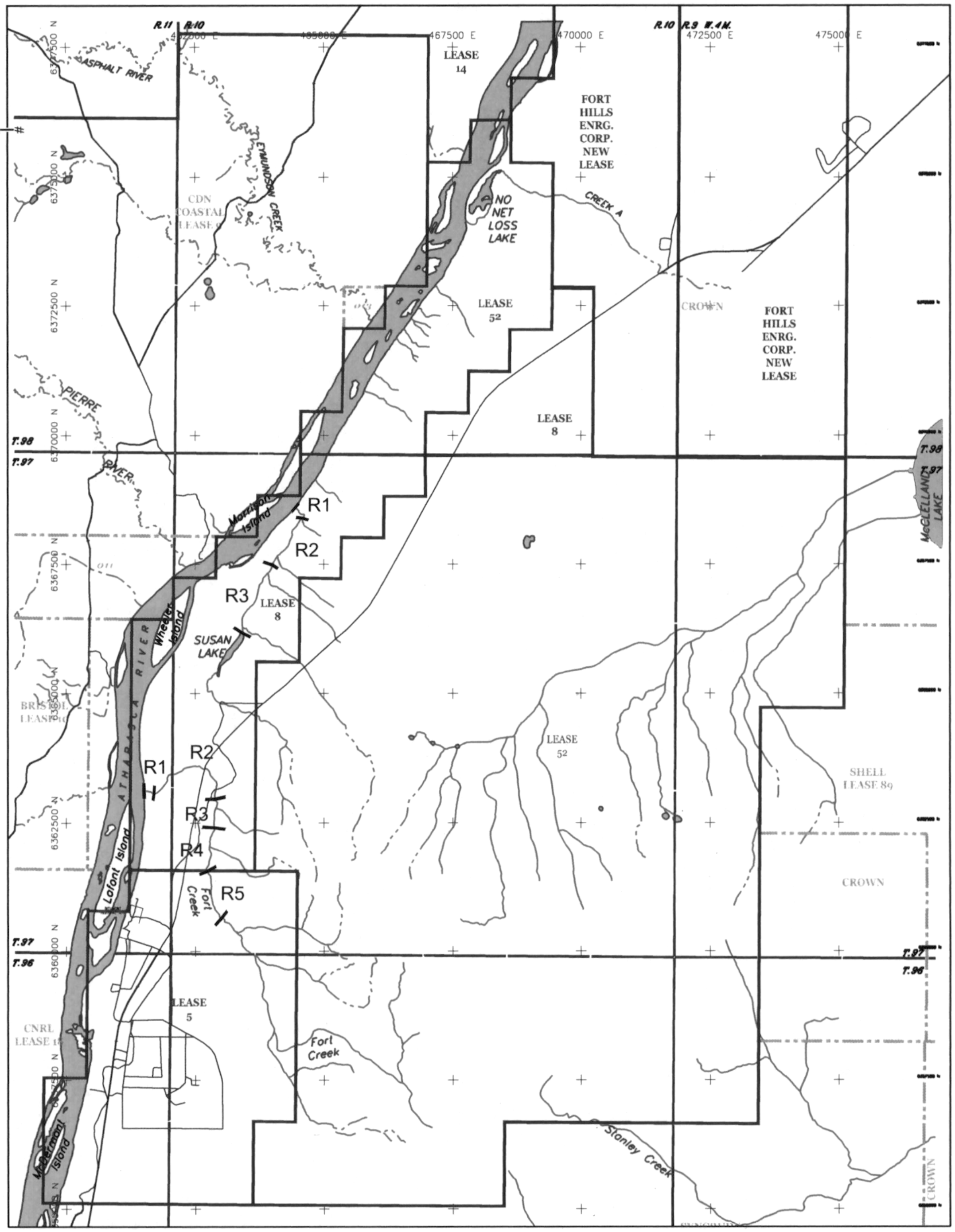
- Spring and Summer 1996 Fisheries investigations conducted for the Syncrude Aurora Mine supplemental baseline program (Golder 1996).
- Fall 1999 Fort Hills Aquatic Baseline Program (Golder 2000).
- 2000/2001 seasonal surveys conducted for the Fort Hills Environmental Baseline Study (TrueNorth 2001).

- 2006 Fort Creek Fish Salvage Efforts (Golder 2007).
- 2006 and 2007 Fort Creek Fish and Fish Habitat Monitoring (Golder 2008b).
- Alberta Environment and Parks (AEP) Fish and Wildlife Management Information System (FWMIS) database (AEP 2019) – containing data collected by Al Pac in 1996; AMEC in 2008 and 2009; Applied Aquatic Research in 2008, 2009 and 2013; Hatfield in 2011, 2012 and 2013, and University of Lethbridge in 2014.
- Regional Aquatics Monitoring data (RAMP 2012, 2013, 2014; AEMERA 2015).
- Fort Hills fall 2017 and fall 2018 Lower Fort Creek Fish and Fish Habitat Surveys.

To facilitate habitat modelling, the Fort Creek channel was divided longitudinally into segments based on differences in fish access and channel morphology that influence fish distribution and habitat characteristics/suitability. The segments are termed Reaches and were numbered sequentially starting at the creek mouth. Fort Creek from the mouth upstream to the current development area was divided into five reaches (Figure 1). Reaches 1 through 4 comprise the portion of the creek downstream of the development area and Reach 5 occurs within the development area.

Habitat modelling was conducted for each reach based on the habitat characteristics of the reach and the fish species known or assumed to be present (i.e., documented in the catch record for the reach or present in an adjacent reach with similar characteristics). The fish distributions for Fort Creek based on all available data are provided in Table 2 along with identification of whether presence was documented or assumed.

Table 3 provides the Reach descriptions and the updated HSI modelling results and HU calculations for Fort Creek within and downstream of the current development area. The total estimate for the HUs present in Fort Creek is 76,091. This estimate is higher than the HU estimate provided in the Conceptual No Net Loss Plan (Golder 2002) due primarily to incorporation of additional data resulting in an increase in the documented number of fish species present in each reach, and due to the inclusion of assumed fish distributions. Detailed habitat modelling results will be provided in the *Fisheries Act* application to be submitted for the Susan Lake watershed HADD as part of the overall modelling update for Fort Hills.



LEGEND

Symbol	Description	Symbol	Description
(thick line)	REACH BOUNDARY	(thin line)	WATERCOURSE
R1	REACH ID	(grey fill)	WATERBODY
(line)	ROAD		

REFERENCE(S)

AltaLIS Ltd. DATA OBTAINED FROM © GOVERNMENT OF ALBERTA 2008.
IHS Inc. DATA OBTAINED FROM IHS Energy Inc.
DATUM: NAD83 PROJECTION: ZONE 12

0 2.5 5
1:125,000 KILOMETRES

CLIENT

FORT HILLS

PROJECT
FORT HILLS OIL SANDS PROJECT

CONSULTANT

GOLDER

YYYY-MM-DD	2019-04-08
DESIGNED	CB
PREPARED	RFM
REVIEWED	MD
APPROVED	CB

TITLE
WATERCOURSE REACH BOUNDARIES

PROJECT NO.	CONTROL	REV.	FIGURE
18101477	2000-CH-0001	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
25 mm

Table 2: Documented and Assumed Fish Species Distribution for Habitat Suitability Modelling

Watercourse	Segment	Fish Species Abbreviation Code														
		BURB	NRPK	LNSC	WHSC	BRST	FTMN	FNDC	LKCH	LNDC	NRDC	PRDC	SLSC	SPSC	SPSH	TRPR
Fort Creek	Reach 1	■	♦■	⌘♦■	♦■	⌘♦■	♦■	♦■	♦■		♦■	⌘♦■	♦■	⌘	■	♦■
	Reach 2	●		♦	●	♦	●	♦	♦	●	●	♦	●			
	Reach 3			●		♦	♦	♦	♦		●	♦				
	Reach 4				●	♦	♦	♦	●		●	●				
	Reach 5					♦						⌘♦				

Note: BURB = Burbot, NRPK = Northern Pike, LNSC = Longnose Sucker, WHSC = White Sucker, BRST = Brook Stickleback, FTMN = Fathead Minnow, FNDC = Finescale Dace, LKCH = Lake Chub, LNDC = Longnose Dace, NRDC = Northern Redbelly Dace, PRDC = Pearl Dace, SLSC = Slimy Sculpin, SPSC = Spoonhead Sculpin, SPSH = Spottail Shiner, TRPR = Trout-perch.

⌘ = Historical data (Golder 1996, RAMP 2004).

♦ = Fort Hills Project data – baseline programs (Golder 2000; TrueNorth 2001), fish rescue operations (Golder 2007), monitoring (Golder 2008b) and lower Fort Creek surveys (Unpublished).

■ = Regional Aquatics Monitoring data – RAMP 2012, 2013, 2014; AEMERA 2015.

● = FWMIS database (AEP 2019) – data collected by Al Pac in 1996, AMEC in 2008 & 2009, Applied Aquatic Research in 2008, 2009 & 2013, Hatfield in 2011, 2012 & 2013, University of Lethbridge in 2014.

[dark grey] = Fish species distribution used for HSI modelling – documented distribution (with symbols); assumed distribution (without symbols).

[light grey] = No documented fish species distribution and species assumed not to be present in the segment.

Table 3: Updated Habitat Suitability Index Modelling Results and Habitat Unit Calculations for Fort Creek

Resource	Reach ID	Reach Description	Fish Species Modelled*	Surface Area [m^2]	Total HSI	Total HUs
Fort Creek	R1	Lower accessible reach – first 300 m upstream from mouth	Burbot, Northern Pike, Longnose Sucker, White Sucker, Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Longnose Dace, Northern Redbelly Dace, Pearl Dace, Slimy Sculpin, Spoonhead Sculpin, Spottail Shiner, Trout-Perch	1,185	7.09	8,402
	R2	Defined channel section from 300 to 1,530 m upstream from mouth	Burbot, Longnose Sucker, White Sucker, Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Longnose Dace, Northern Redbelly Dace, Pearl Dace, Slimy Sculpin	4,428	6.35	28,118
	R3	Section of mixed beaver impoundments and defined channel from 1,530 to 2,979 m upstream from mouth	Longnose Sucker, White Sucker, Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Northern Redbelly Dace, Pearl Dace	4,202	4.83	20,296
	R4	Section of mixed beaver impoundments and poorly defined channel from 2,979 m to current development area (4,000 m upstream from mouth)	Longnose Sucker, White Sucker, Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Northern Redbelly Dace, Pearl Dace	1,736	4.77	8,281
	R5	Section of mixed beaver impoundments and poorly defined channel within current development area	White Sucker, Brook Stickleback, Fathead Minnow, Finescale Dace, Lake Chub, Northern Redbelly Dace, Pearl Dace	2,599	4.23	10,994
			Total	**14,150**	-	**76,091**

*Includes documented and assumed fish species distributions as per Table 2.

Based on the NNLL having been constructed and now operating, combined with the assessment of lack of effects to date on the productivity of lower Fort Creek due to the current development in the upper watershed, and as per Authorization AB00-517-2013, Condition 3.8.2, the compensation ratio to account for the reduced time-lag between habitat effects and maturation of the compensation habitats in the NNLL. The proposed offset ratios for Fort Creek are as follows:

- 2:1 for losses sustained to date in Fort Creek (Reach 5, in the current development area); and
- 1.5:1 for the remainder of Fort Creek (Reaches 1 through 4).

Based on the proposed compensation ratios, the total compensation requirement for Fort Creek is 119,632 HUs.

3.0 REFERENCES

AEMERA (Alberta Environment Monitoring, Evaluation and Reporting Agency). 2015. Regional Aquatics Monitoring in Support of the Joint Oil Sands Monitoring Plan 2014 Program Report. Prepared for the Alberta Environment Monitoring, Evaluation and Reporting Agency by Hatfield Consultants, Kilgour and Associates Ltd. and Western Resource Solutions. April 2015.

AEP (Alberta Environment and Parks). 2019. Fish and Wildlife Management Information System Database – Fish and Wildlife Internet Mapping Tool. Located at: https://www.alberta.ca/access-fwmis-data.aspx#toc-0. Accessed March 2019.

Golder (Golder Associates Ltd.). 1996. Addendum Report to Syncrude Aurora Mine Environmental Baseline Program: Spring and Summer 1996 Fisheries Investigations. Submitted to Syncrude Canada Ltd., Fort McMurray, Alberta. September 1996.

Golder. 2000. Fall 1999 Aquatics Baseline Program for the Fort Hills Oil Sands Project. Submitted to Koch Exploration Canada Ltd., Calgary, Alberta. August 2000.

Golder. 2002. Fort Hills Oil Sands Project Conceptual No Net Loss Plan. Submitted to TrueNorth Energy LP. December 2002.

Golder. 2005. Shell Jackpine Mine – Phase I. No Net Loss Habitat Compensation Plan, Fish Species Habitat Suitability Index Models Supporting Documentation. Prepared for Shell Canada Ltd. February 2005.

Golder. 2006. Fort Hills Oil Sands Project No Net Loss Plan, Volume I – Main Report. Submitted to Fort Hills Energy Corporation. September 2006.

Golder. 2007. Fort Hills Oil Sands Project Summary of Fish Salvage Efforts on Fort Creek Fall and Winter 2006. Submitted to Petro-Canada oilsands Inc. March 2007.

Golder. 20008a. Fish Species Habitat Suitability Index Models for the Alberta Oil Sands Region. Version 2.0. October 2008.

Golder. 2008b. Fort Hills Oil Sands Project Fort Creek Fish and Fish Habitat Monitoring 2006 and 2007. Submitted to Petro-Canada Oil Sands Inc. November 2008.

RAMP (Regional Aquatics Monitoring Program). 2004. Review of Historical Fisheries Information for Tributaries of the Athabasca River in the Oil Sands Region. Oil sands regional Aquatics Monitoring Program (RAMP) 2004. February 2004.

RAMP. 2012. Regional Aquatics Monitoring Program 2011 Technical Report – Final. Prepared for the RAMP Steering Committee by the RAMP 2011 Implementation Team – Hatfield Consultants, Kilgour and Associates Ltd. and Western Resource Solutions. April 2012.

RAMP. 2013. Regional Aquatics Monitoring Program 2012 Technical Report – Final. Prepared for the RAMP Steering Committee by the RAMP 2012 Implementation Team – Hatfield Consultants, Kilgour and Associates Ltd. and Western Resource Solutions. April 2013.

RAMP. 2014. Regional Aquatics Monitoring Program 2013 Technical Report – Final. Prepared for the RAMP Steering Committee in Support of the JOSMP by the RAMP 2013 Implementation Team – Hatfield

Consultants, Kilgour and Associates Ltd. and Western Resource Solutions. April 2014.

TrueNorth (TrueNorth Energy LP). 2001. Application for Approval of the Fort Hills Oil Sands Project. [Volume 2: Environmental Baseline Study]. Application and Environmental Impact Assessment. June 2001.

Hatfield CONSULTANTS
Environmental Specialists Since 1974



Mrs. T's Lake Monitoring Program 2018 Technical Report

April 2019

Prepared for:
Canadian Natural Resources Ltd.
Calgary, Alberta

#200 - 850 Harbourside Drive, North Vancouver, British Columbia, Canada V7P 0A3 • **Tel: 1.604.926.3261** • Fax: 1.604.926.5389 • **www.hatfieldgroup.com**

Hatfield
CONSULTANTS

MRS. T'S LAKE MONITORING PROGRAM

2018 TECHNICAL REPORT

Prepared for:

CANADIAN NATURAL RESOURCES LTD.
1229 855 – 2 STREET SW
CALGARY, AB
CANADA T2P 4J8

Prepared by:

HATFIELD CONSULTANTS
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3

APRIL 2019

CNUL9184
VERSION 2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

ADCP	Acoustic Doppler current profiler
ADV	Acoustic Doppler velocimeter
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resource Development
BC MOE	British Columbia Ministry of Environment
CNRL	Canadian Natural Resources Limited
DFO	Department of Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
EPEA	Environmental Protection and Enhancement Act (Alberta)
FSL	Full supply level
GPS	Global positioning system
GW	Groundwater
HADD	Harmful alteration, disruption, and destruction
HEC-RAS	Hydrologic Engineering Center's River Analysis System
JOSMP	Joint Oil Sands Monitoring Program
JPM	Jackpine Mine
MRME	Muskeg River Mine Expansion
MSL	Mineral surface lease
NNLP	No Net Loss Plan
SDR	Stage-discharge relationship
TDL	Temporary diversion licence
USGS	United States Geological Survey
WSC	Water Survey of Canada
WY	Water year (November 1 to October 31)

EXECUTIVE SUMMARY

In October 2013, Fisheries and Oceans Canada (DFO) issued an amendment to Fisheries Act Authorization (no. ED-05-3287-2) which approved Shell Energy Canada (Shell) to construct and operate a compensation Lake (the Lake) within the Jackpine Mine lease area. DFO also approved a revised No Net Loss Plan (NNLP) and Detailed Design (Norwest 2013) as a condition of this amended Authorization. The Lake was designed to offset harmful alteration, disruption, and destruction (HADD) of fish habitat resulting from the Muskeg River Mine Expansion Project (the Project) at a minimum 2:1 compensation ratio. As an offline Lake, diversion of the Muskeg River was necessary to fill the basin. Thresholds for Muskeg River diversions to the Lake were proposed in Shell's No Net Loss Plan (Shell 2013) and submitted to DFO and Alberta Energy Regulator (AER). The thresholds were based on the Muskeg River Interim Management Framework for Water Quantity and Quality (Alberta Environment 2008), which recommends that Muskeg River diversions should not exceed 15% of the Muskeg River flow. Amended Temporary Diversion Licences (TDL nos. 00394627 and 00410160) were issued to Canadian Natural following their acquisition of the Project in June 2017, to divert up to 1,790,259 m^3 from Muskeg River to the Lake from the dates of June 1, 2017 to April 30, 2018 and from May 1, 2018 to May 2, 2019, respectively.

Construction of the Lake basin was completed in April 2016 (Norwest 2017). Norwest issued a Construction Completion Certificate on behalf of Shell Canada, which was accepted by DFO. Lake filling commenced when diverted flows from the Muskeg River entered the Lake. A hydrometric monitoring network was installed to monitor Lake levels and diversions from the Muskeg River to the Lake. Monitoring in 2016 and 2017 indicated that the Lake was not filling at rates expected in the detailed design. Shell (now Canadian Natural) contracted Hatfield Consultants (Hatfield) in April 2017 to operate the hydrometric monitoring network and assess the ability of the inlet channel to convey water under different Muskeg River flow scenarios. Findings of the assessment verified that the elevation of the Inlet Invert was too high to convey design flows to the Lake during normal ranges of flow in the Muskeg River. Canadian Natural obtained approval from the AER and DFO to lower the inlet channel and Inlet Invert to an elevation that would allow the Lake to fill more effectively, with repairs to the inlet channel completed in March 2018. Canadian Natural proposed and received AER and DFO approval to further lower the inlet channel (beyond design) to 277.4 masl as a risk management measure to ensure lake filling.

Repairs to the inlet channel resulted in increased diversions to the Lake during the April to May 2018 freshet floods. The Lake filled, reaching the FSL on May 4, 2018. Filling of the Lake triggered the closure of the TDL and initiation of Year One monitoring as specified in the 5-Year Plan, which included assessments of hydrology, water quality, sediment quality and sublethal toxicity, fish passage, and inlet and cutlet channel stability. Upon filling, the Lake also spilled to the outlet channel, which conveyed flow to the Muskeg River for 37 days in 2018. The inlet channel maintained consistent surface water flow from March to the end of the Year One monitoring period (October 31, 2018).

Hatfield conducted six field visits to the hydrometric stations in 2018, and an additional seventh visit to the inlet channel station. Visits included station maintenance and equipment installation, downloading continuous data, and conducting manual stage and discharge measurements at stations located on the Lake, the inlet and outlet channels, and Muskeg River. Stage-discharge relationships were developed for the Muskeg River near the inlet, the inlet channel, and the outlet channel; continuous discharge data were then derived for each of these locations.

Regional data from the C1 Aurora Climate Station indicated that climate conditions in 2018 were wetter and warmer than the historical averages. Large fluctuations in air temperature were evident in 2018, with the highest and lowest respective maximum and minimum monthly air temperatures on record for most months of 2018. Discharge data from Water Survey of Canada Station 07DA008 on the Muskeg River indicated regional flows were lower than average in most months of the 2018 Water Year (November 1, 2017 to October 31, 2018).

Continuous discharge data derived for the inlet channel estimated a reportable diversion volume of 1,609,805 m^3 from Muskeg River to the Lake occurred between November 1, 2017 and May 4, 2018 (date of Lake filling, after which the TDL was closed). The inlet discharge data demonstrated that diversions did not exceed thresholds set in the TDL, with the total diversion representing 81% of the volume allocated in the TDL. However, diversions did exceed 15% of Muskeg River flows for 24 days in 2018, which may have affected the downstream hydrology of the Muskeg River. Discussions between Canadian Natural and AER in November 2017 identified a diversion threshold to minimize impacts to the Muskeg River, where no diversions to the inlet channel were to occur at Muskeg River flows below 0.51 m^3/s; however, issues with the stability of the Inlet Invert resulted in diversions occurring from March 20 to April 14, 2018, when Muskeg River flows were below 0.51 m^3/s. It should be noted that daily diversions at this time only accounted for approximately 3% of Muskeg River flows. From April 15 onwards, Muskeg River flows were above the 0.51 m^3/s diversion threshold.

Lake bathymetry data from the detailed design (Norwest 2017) and continuous level data from the hydrometric stations were used to calculate daily Lake volumes for 2018. Lake volume increased by 1,507,412 m^3 over the 2018 WY, culminating in a total volume of 2,064,838 m^3 and 90% FSL capacity. Daily Lake volume, precipitation, evaporation, and inlet and outlet channel flow data were used to calculate a 2018 water balance for the Lake. The water balance results indicated that the Lake is holding water as designed, and that surface water inputs (inlet channel flow) and groundwater were the most significant components affecting Lake storage volume changes over the 2018 WY.

Sustained flow recorded in the inlet channel between March 18 and October 31, 2018 consistently provided water depths greater than 0.1 m, which was the minimum prescribed depth for fish passage in the No Net Loss Plan. Intermittent flow in the outlet channel may have also provided fish passage between the Muskeg River and the Lake in 2018. There were no observations of flow obstructions in the channels, and no stranded fish or mortalities were observed.

During April 2018 freshet flows, large amounts of channel erosion and head cutting occurred in the inlet channel, resulting in bed scour measured as high as 0.6 m. Subsequent elevation surveys of key locations in the inlet indicated that channel elevation stabilized after the freshet event, remaining relatively unchanged for the remainder of the 2018 WY. The geomorphic stability of the outlet channel was not assessed in 2018, due to only 37 days of low magnitude discharge (less than 0.2 m^3/s).

Analytical water chemistry was sampled in the pelagic and littoral zones of the Lake in July and September (summer and fall) 2018. Limnological depth profiles and in situ water quality measurements were also collected at these locations in July, August, and September. A monitoring buoy outfitted with continuous-monitoring water quality sondes at near surface, mid-water column, and near bottom depths was also installed at the mid-lake station in August. Results of continuous and in situ water quality monitoring indicated that the lake was thermally stratified during the summer months. DO concentrations in the Lake

were below guidelines for the protection of aquatic life (GoA 2018) at depths greater than 4 m until seasonal mixing occurred in fall. pH remained within guidelines during the open-water period. Concentrations of all analytical water quality variables except iron and boron were below guidelines for the protection of aquatic life (GoA 2018) in 2018. These exceedances are considered representative of naturally occurring conditions in the local study area, with similar observations commonly occurring in the Muskeg River watershed.

Sublethal toxicity testing was completed on sediments collected from the mid-lake and littoral stations in August. 2018 sediment toxicity test results indicated that pelagic sediments had an ecologically significant effect on the growth of *Hyalella*; however, all sediment quality analytes were below the interim sediment quality guidelines and probable effect levels in 2018, and there were no toxic effects on invertebrate survival observed in the lab testing, suggesting the Lake sediments are capable of supporting a diverse community of aquatic invertebrates.

DISTRIBUTION LIST

The following individuals/firms have received this document:

Name	Firm	Hardcopies	CDs	Email	FTP
Darryl Chudobiak	Canadian Natural Resources Ltd.	-	-	✓	-

AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Mrs. T's Lake Monitoring Program – 2018 Technical Report	20190315	Daniel Moats Project Director	Chris Jaeggle Project Manager
2	Second version of Mrs. T's Lake Monitoring Program – 2018 Technical Report	20190412	Daniel Moats Project Director	Chris Jaeggle Project Manager

1.0 INTRODUCTION

1.1 BACKGROUND

Shell Canada Energy Limited (hereafter Shell) was issued an amended Authorization from Fisheries and Oceans Canada (the Authorization, ED-05-3287-2, DFO 2013) for the Muskeg River Mine Expansion Project (the Project) in October 2013. The Authorization requires the proponent to develop a compensation lake that provides a minimum 2:1 compensation ratio for the habitat affected by the Project. A revised No Net Loss Plan (NNLP; Shell 2013) developed to address amendments to the Authorization included provisions for sport and forage fish habitat compensation to offset expected harmful alteration, disruption, or destruction (HADD) of fish habitat associated with the Project.

The detailed design of the Muskeg River Mine Expansion Compensation Lake (henceforth referred to as Mrs. T's Lake, or the Lake) stipulated that filling would occur by diverting water from the Muskeg River (Norwest 2013). The NNLP states that Muskeg River water diversions should not exceed 15% of the flow in the Muskeg River under non-flooding conditions, and that no diversions should occur during low flow periods. These diversion guidelines were based on recommendations from the Muskeg River Interim Management Framework for Water Quantity and Quality (Muskeg River Framework, Alberta Environment 2008).

Construction of the Lake basin was completed in spring 2016 (Norwest 2017), and filling was initiated via a constructed inlet channel that connects the Lake to and draws flows from the Muskeg River. An outlet channel has also been commissioned to return flows to the Muskeg River once filling of the Lake has been completed. The Lake has a total surface area of 41.4 ha at Full Supply Level (FSL), including 18 ha (43.7 %) of littoral zone habitat. The Lake design provides a mean depth of 5.7 m and a maximum depth of 12.2 m at FSL. Both the inlet and outlet channels have bottom bed widths of 1 m and bank slopes with 2H:1V aspect ratios (Norwest 2013), and incorporate design specifications to facilitate fish movement between the Lake and the Muskeg River under FSL conditions and when Muskeg River flows are above 1.58 m^3/s.

Hatfield Consultants (Hatfield) developed a monitoring plan for the first five years following commissioning (filling) of the Lake (Hatfield 2016). The 5-Year Plan (or Program) is designed to satisfy requirements of the DFO Authorization and includes provisions for evaluating the effectiveness of the compensation habitat, including surface hydrology, water quality, and sediment quality assessments, and aquatic vegetation, plankton, benthic invertebrate, and fish community monitoring.

In June 2017, operation of the Project transitioned from Shell to Canadian Natural Resources Limited (Canadian Natural) on behalf of Canadian Natural Upgrading Limited. This transition included the transfer of the Temporary Diversion License (TDL# 00394627) issued by the Alberta Energy Regulator (AER 2017a) to divert water from Muskeg River to the Lake. The TDL allocated a maximum diversion volume of 1,790,259 m^3, and a maximum instantaneous diversion rate of 2.36 m^3/s. Hatfield was contracted by Canadian Natural to conduct monitoring of the Lake, the inlet and outlet channels, and the Muskeg River at the Lake inlet and outlet in 2017. This monitoring was undertaken in addition to requirements listed in the 5-Year Plan, for the purpose of providing information on the hydrology of the Lake during filling, and to document compliance with the TDL conditions. The Lake only partially filled in 2017 and the hydrometric monitoring initiative was extended into 2018. Canadian Natural received approval from AER to undertake repairs to the inlet channel in March 2018, to allow flows to be diverted to the Lake during lower discharge periods in the Muskeg River.

From April to May 2018, a portion of the Muskeg River freshet floods were effectively diverted to the inlet channel, culminating in Lake filling to FSL on May 4, 2018. Diversions occurring between May 1 to 4, 2018 fell under the amended TDL (no. 004101060, AER 2017b). Filling of the Lake effectively closed the TDL and triggered the initiation of monitoring for Year One of the 5-Year Plan. Year One monitoring was initiated in May 2018, and consisted of water quality, sediment quality and sublethal toxicity, fish passage, and inlet and outlet channel stability assessments, as well as the continuation of hydrometric monitoring.

1.2 PURPOSE

Year One of the Program was initiated in May 2018 after the Lake reached FSL. The Year One program was undertaken to fulfill Authorization requirements to monitor Lake conditions, while the supplemental monitoring conducted between November 2017 and May 2018 was undertaken to assess the diversion of flows from Muskeg River to the Lake prior to filling to FSL. The primary objectives of these studies were:

1. Quantify and assess Muskeg River flows and diversions to the Lake;
2. Assess the hydrology of the Lake;
3. Monitor and assess water and sediment quality conditions in the Lake;
4. Assess fish passage to and from the Lake; and
5. Assess the geomorphic stability of the constructed inlet and outlet channels.

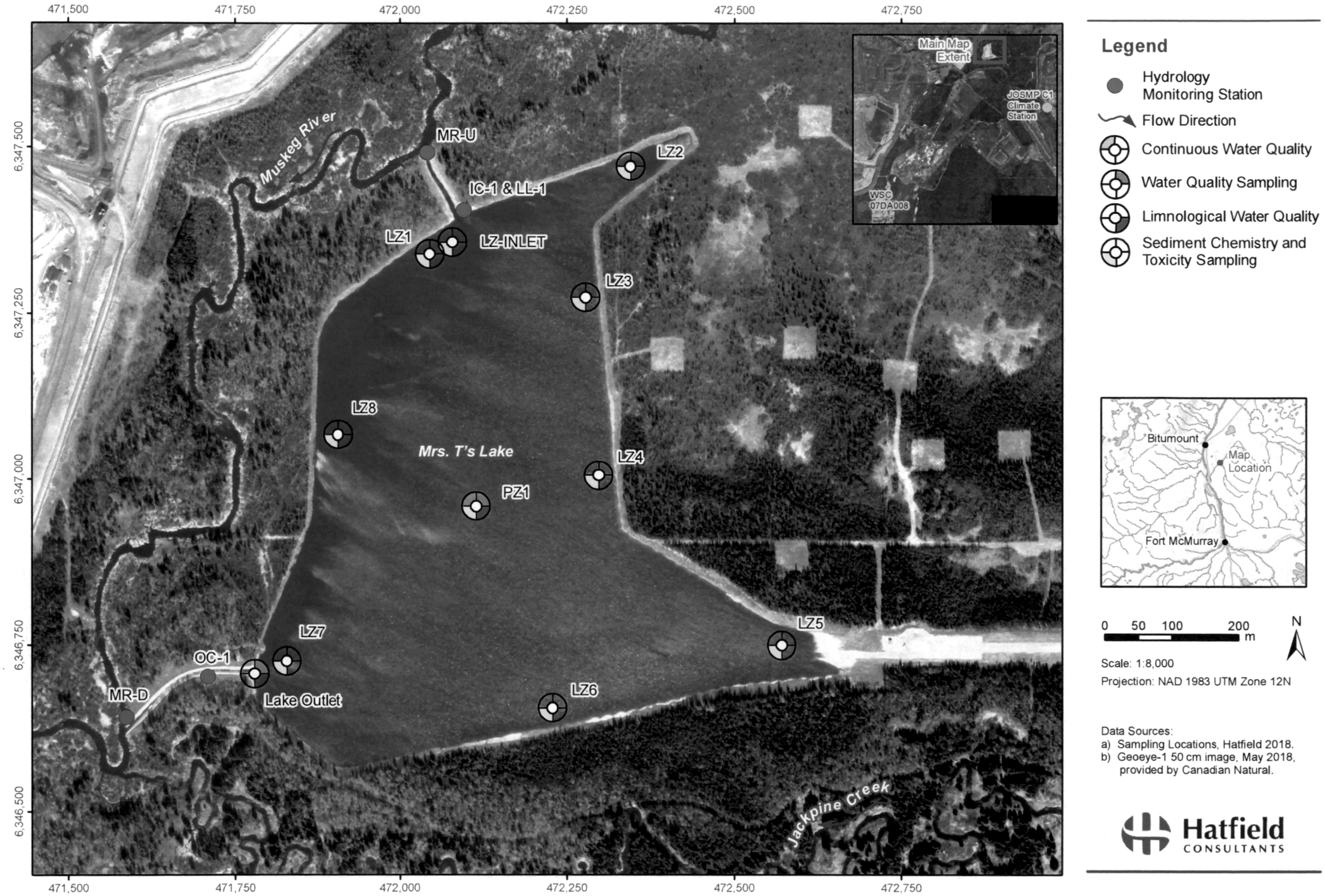
This report provides detailed discussions on the monitoring station locations and variables monitored (Section 2.1), field and data analysis methods (Section 2.2 and 2.3, respectively), and results of the 2018 Water Year (November 1, 2017 to October 31, 2018) monitoring activities (Section 3.0). Results and conclusions are provided in Section 4.0 and recommendations for the 2019 monitoring program are provided in Section 5.0. Detailed quality assurance/quality control (QA/QC) data are provided in Appendix A1, surface water hydrology data are provided in Appendix A2, surface water quality data are provided in Appendix A3, and sediment quality and toxicity data are provided in Appendix A4.

1.3 ENVIRONMENTAL SETTING

Mrs. T's Lake is positioned within the Jackpine Mine Mineral Surface Lease, approximately 100 km north of Fort McMurray, Alberta. The Lake is located within the Muskeg River catchment, approximately 250 m northeast of the confluence of the Muskeg River and Jackpine Creek. The section of the Muskeg River adjacent to the Lake is generally characterized by a u-shaped channel with low banks, and low-gradient, slow-flowing water. Channel substrate is dominated by fine materials, and beaver activity and impoundments are present in the area.

The Lake covers an area of approximately 41.4 ha at FSL (Norwest 2013) and has a roughly rectangular shape with a north-south axis length of approximately 800 m and west-east axis of approximately 500 m. An inlet channel connects Muskeg River to the northwest corner of the Lake, and an outlet channel returns flow to the Muskeg River from the southwest corner of the Lake (Figure 1). Access to the Lake is by an all-weather road that connects with the Jackpine Mine Imperial Oil Limited Road. The location of the Lake relative to the Athabasca oil sands region is provided in Figure 1 below.

Figure 1 Mrs. T's Lake monitoring locations, 2018.



Mrs. T's Lake Monitoring Program

K:\Data\Project\CNUL9184-NV\A_MXD\CNUL9184_MRMEMonitoringStations_20190315_v0_10_SS.mxd

2.0 METHODOLOGY

2.1 YEAR ONE STUDY DESIGN

As specified in the 5-Year Plan (Hatfield 2016), Year One monitoring consisted of continuous and discrete hydrology, continuous water quality, analytical water chemistry, limnological water quality, analytical sediment chemistry, and sediment toxicity testing of the Lake, and fish passage and geomorphic assessments of the inlet and outlet channels. Table 1 lists all monitoring activities completed in Year One as specified under the 5-Year Plan and Table 2 lists the Program monitoring stations and the variables recorded at each location. Figure 1 shows the locations of the monitoring stations, and the Lake location relative to the Athabasca oil sands region. Additional details on continuous monitoring station equipment, benchmarks, and station layouts are provided on the Site Information Sheets in Appendix A5.

Table 1 Year One sampling undertaken in support of Mrs. T's Lake Monitoring Program.

Sampling Activity	Sampling Frequency	Sampling Locations	Notes
Water Chemistry	Quarterly	PZ1 and Outlet locations	Sampling completed in July and September (i.e., summer and fall) only
Limnological Water Quality Assessment	Once per month in March, June, July, August, and September	PZ1	Assessments completed in July, August, and September
Sublethal Toxicity Testing (sediments)	Once in August	PZ1, Lake Inlet	One-time sampling event in inlet, required in 2018 only
Sediment Chemistry (Lab)	Once in August	PZ1, Lake Inlet	One-time sampling event in inlet, required in 2018 only
Water Quality (Continuous)	Every 15 Minutes from May to October (dependent on ice conditions)	PZ1	Continuous monitoring was completed at PZ1 from August to October
Lake Level, Inlet, and Outlet Gauging (Continuous)	Every fifteen minutes from November to October (water year)	LL-1, IC-1, and OC-1	
Muskeg River Gauging (Continuous)	Every fifteen minutes from November to October (water year)	MR-U and MR-D	
Lake Level and Outlet Gauging (Continuous)	Every fifteen minutes from November to October (water year)	OC-1	
Channel Stability of Lake Inlet and Outlet	May and September	Inlet and Outlet Channels	Completed only at the inlet channel
Fish Passage	May and September	Inlet and Outlet Channels	

Table 2 Mrs. T's Lake monitoring mtations.

Station Name	Station ID	UTM Coordinates (Zone 12V)	Variables Monitored
Lake Level	LL-1	472096 E, 6347404 N	Water level, water temperature
Lake Inlet Channel	IC-1		Discharge, water level, water temperature, Inlet Channel photos
Lake Outlet Channel	OC-1	471709 E, 6346702 N	Water level, water temperature, barometric pressure, air temperature
Muskeg River at Lake Inlet Channel	MR-U	472041 E, 6347491 N	Discharge, water level, water temperature
Muskeg River Upstream of Lake Outlet Channel	MR-D	471587 E, 6346641 N	Water level, water temperature
Pelagic Zone	PZ1	472115 E, 6346958 N	In-situ and analytical water chemistry, sediment chemistry and toxicity, limnological profiles, continuous water quality
Littoral Zone	LZ1	472045 E, 6347338 N	Sediment chemistry and toxicity
Littoral Zone	LZ2	472345 E, 6347470 N	Sediment chemistry and toxicity
Littoral Zone	LZ3	472278 E, 6347273 N	Sediment chemistry and toxicity
Littoral Zone	LZ4	472298 E, 6347005 N	Sediment chemistry and toxicity
Littoral Zone	LZ5	472571 E, 6346749 N	Sediment chemistry and toxicity
Littoral Zone	LZ6	472229 E, 6346655 N	Sediment chemistry and toxicity
Littoral Zone	LZ7	471828 E, 6346725 N	Sediment chemistry and toxicity
Littoral Zone	LZ8	471906 E, 6347067 N	Sediment chemistry and toxicity
Outlet of Lake	Outlet	471779 E, 6346706 N	In situ and analytical water quality
Inlet of Lake	LZ-INLET	472079 E, 6347356 N	Sediment chemistry and toxicity

2.2 FIELD DATA COLLECTION

2.2.1 Hydrology

Hydrology monitoring in 2018 consisted of six routine visits to the hydrometric stations listed in Table 1, including visits in April, May, June, August, September, and October. An additional visit to IC-1 was conducted in late April.

2.2.1.1 Hydrometric Stations

Each of the hydrometric stations listed in Table 2 were configured to collect near-continuous measurements of water level and water temperature. The data collection interval at each station was set to 15 minutes, and water level and temperature data were collected using a calibrated, submersible pressure transducer connected to an external datalogger. All hydrometric stations, excluding MR-D, were equipped with cellular telemetry to facilitate near-real-time data transmissions to Hatfield's internal hydrometric database. Logging equipment was contained inside weather-proof enclosures that were mounted to steel signposts driven into the ground. Power supplies consisted of 12 V batteries charged by solar panels. The pressure transducers designated for stations IC-1 and LL-1 were configured to the same external datalogger, power supply, and telemetry system.

Hydrometric station visits included downloading hydrometric data and servicing automated monitoring equipment, replacing station desiccant, and installing new hardware on an as-needed basis. Equipment deployments completed in 2018 included replacement of the existing Levelogger sensor with an OTT pressure level sensor (PLS) at OC-1 and establishing new survey benchmarks at OC-1.

2.2.1.2 Water Level Surveys

Manual water level surveys were completed during each 2018 field visit to MR-U, MR-D, OC-1, LL-1, and IC-1. Procedures for conducting water level surveys were derived from standards published by BC Ministry of Environment (BC MOE 2009). Water level elevations were measured to the nearest 0.001 m with an Engineer`s level. Each survey consisted of two setups, with an acceptable level difference of <0.004 m between the two measurement sets. Surveys were conducted using three independent benchmarks as elevation controls at each station, with water level elevations measured directly above or adjacent to the pressure transducer. The geodetic datums assigned to the benchmarks at each station were derived from a precision GPS survey conducted by Canadian Natural staff in September 2017.

2.2.1.3 Discharge Measurements

Discharge measurements were completed during each 2018 field station visit to MR-U, IC-1, and OC-1 in 2018. Streamflow measurements were collected using either the wading area-velocity method or the Acoustic Doppler Current Profiler (ADCP) method, with procedures consistent with Water Survey of Canada (WSC 2001, 2013), United States Geological Survey (USGS 1982), and BC MOE (BC MOE 2009) recommendations and protocols. Measurement standards are summarized below:

Area-Velocity Method

- Number of verticals: minimum of 20, or at a minimum spacing of 0.05 m in small streams;
- Number of velocity observations per vertical measurement:
    - Where depth was 0.75 m or less, one observation was made at 60% of the depth below the surface;
    - For depths greater than 0.75 m, observations were made at 20% and 80% of the depth below the surface; and
- Velocity averaging: 40-second averages were measured using a Sontek FlowTracker ADV (Acoustic Doppler Velocimeter).

ADCP Method

- Configure the ADCP with site-specific information and settings, including the site name, crew member names, transducer depth, and magnetic declination of the measurement location (approximately 13.65 degrees for Fort McMurray in 2018).
- Complete and pass system tests and compass calibration during the setup procedure.
- Navigate the ADCP across the measurement cross-section in a direction perpendicular to the flow, ensuring a steady pace where the velocity of the moving ADCP does not exceed the velocity of the water in the channel.

- Calculate streamflow from a minimum of four "good" passes of the cross-section. A "good" pass met the following criteria: (i) each pass was within 5% of the mean measured discharge; (ii) at least 50% of the total calculated discharge in a pass was measured; (iii) the flow angle was minimal; (iv) the pitch and roll of the measurement platform was less than 5%; and (v) a minimum of ten ensembles were measured at the start and end positions of each pass.

2.2.1.4 Cross-Section Surveys

Five cross-sections were surveyed on the Outlet Channel during the September and October field visits, beginning with a cross-section located 30 m downstream of the Lake Outlet and ending with one located 110 m downstream of the Outlet. Data generated from these cross-section surveys were used to develop a HEC-RAS model for the Outlet Channel. Figure 2 shows the locations of each of the cross-section surveys.

A tape measure was affixed to the top of each bank, running perpendicular to the channel flow. Each cross-section survey included level elevation measurements of multiple points within the channel, and a measurement of the horizontal distance between the left and right tops of bank. Elevations were measured at the approximate top of each bank, select locations between the top of each bank and the water edge, the water edge on each bank, and multiple locations within the wetted channel including the thalweg (deepest location in the channel). Elevations were measured to the nearest 0.001 m using an Engineer's level, tripod, and survey rod, and referenced to the geodetic datum of the benchmark located at the OC-1 hydrometric station.

Figure 2 Cross-section survey locations on the Lake outlet channel, 2018.



Mrs. T's Lake Monitoring Program

K:\Data\Project\CNUL9184-NV\A_MXD\CNUL9184_MRMECrossSectionSurveys_20190315_v0_6_SS.mxd

2.2.1.5 Data Gaps

Temporary interruptions to the hydrometric network resulted in the following data gaps during the Year One program:

- Several small data gaps of up to several hours occurred as a result of routine field visit activities at all stations;
- A data gap from February 27 to March 20 occurred when the IC-1 station was disconnected during construction repairs to the Inlet Channel; however, no flow was present in the channel during this time;
- There was a brief interruption to data collection at OC-1 while the water level sensor was replaced during the June 5, 2018 field visit;
- The quality of IC-1 water level data collected from April 24 to 27 has been classified "uncertain". High freshet flood volumes and large amounts of channel erosion dislodged the water level sensor and swept it downstream, possibly affecting the sensor water depth readings during this period;
- The water level sensor at IC-1 also became buried by eroded material from April 24 to 27. On April 27, a data gap of less than 2 hours occurred when the station was disconnected to unbury and reposition the sensor and attach an anchor line to the sensor weight to relieve strain on the sensor cable; and
- A data gap at IC-1 occurred from May 30 to June 5, 2018 when the station power supply was disconnected during a wildlife encounter. Power was reconnected during the June 5 field visit.

2.2.2 Water Quality

2.2.2.1 Continuous Water Quality

Temperature loggers were deployed at the water surface and at one-metre intervals through the water column at PZ-1. The recording period for the loggers extended from July 24 to October 18, 2018, with observations collected at 15-minute intervals.

Three datasondes (YSI EXO3) were deployed from a buoy positioned at PZ-1, to collect temperature, conductivity, dissolved oxygen (DO), and pH at 0.5m (surface), 6m (middle), and 11m (bottom) depths. The 2018 period of record extended from August 23 to October 19, with observations collected at 15-minute intervals.

2.2.2.2 In Situ and Limnological Water Quality

A YSI PRO DSS multi-meter was used to collect depth profile measurements of dissolved oxygen (DO) (± 0.01 mg/L), temperature (± 0.01 °C), pH (± 0.01 pH units), and conductivity (± 0.01 µS/cm) at one-metre intervals through the water column at station PZ-1 in July, August, and September. At the Lake surface, supplemental measurements of DO were collected using a LaMotte portable Winkler titration kit, and temperature, pH, and specific conductivity were collected with a calibrated multi-meter Hanna pen to confirm the accuracy of the YSI multi-meter.

Secchi depth measurements were recorded at each pelagic site in order to estimate the depth of the euphotic zone. The maximum depth observable was measured on the descent and ascent of the disc though the water column; the two depths were then averaged to provide the Secchi depth for each site. The euphotic zone was defined as twice the Secchi depth (Wetzel 2001).

In situ water quality observations were also used as quality control checks on the continuous and analytical water quality sampling results.

2.2.2.3 Analytical Water Quality

Seasonal water quality sampling was completed at PZ-1 and the Lake Outlet station on July 24 and September 13, 2018 (Figure 1). A Garmin 60 handheld GPS was used to navigate to each station, which were accessed using a 10-foot inflatable boat equipped with a 15-horsepower outboard engine.

Water quality grab samples were collected from just below the water surface at both stations, and a near-bottom sample was also collected from one meter above the lake bottom (11 m depth) at PZ-1, using a four-litre Van Dorn sampler. The Van Dorn was washed with a metals-free soap (i.e., Alcanox), then triple-rinsed with ambient lake water prior to deployment, and bottles were directly filled from the Van Dorn upon retrieval.

QA/QC procedures included the collection of one duplicate sample for each sampling event. A field blank was also analyzed for the fall sampling event, and trip blanks were analyzed for the summer and fall programs.

Water samples were collected and preserved in labeled bottles and shipped according to protocols specified by the consulting laboratories. All laboratory analyses were conducted by ALS Laboratory Group (ALS) in Fort McMurray.

2.2.3 Sediment Quality

Discrete sediment samples were collected from the mid-lake station (PZ-1) and the inlet channel (IC-1), and a composite sample (LIT-COMP) was collected from the eight littoral zone stations on August 23, 2018 (Figure 1). A Garmin 60 handheld GPS was used to navigate to each station, which were accessed using a 10-foot inflatable boat equipped with a 15-horsepower outboard engine.

At each station, sediments were collected with a 15cm x 15cm Ekman grab (0.023 m^2 sampling area). To minimize potential for sample contamination, stainless steel pans, spoons, and the dredge were cleaned with a metals-free soap (i.e., Alconox), rinsed with hexane and acetone, and then triple-rinsed with ambient water prior to each sample collection. A grab sample was successful if the jaws closed completely and the entire bottom of the sampler contained a layer of sediment. Successful grabs were transferred to a stainless-steel pan until a sufficient volume had been collected for analysis. The number of grabs required to obtain sufficient volume was recorded. The sediments were then homogenized in the pan using a stainless-steel spoon and transferred into sterilized glass jars for chemical analyses and sealable plastic bags for the particle size and total organic carbon (TOC) analyses and sediment toxicity assays. Each container was labeled with the site name, collection date and time, and the analysis requested. All sediment samples were kept in coolers and maintained at approximately 4°C. Samples were packed with ice for shipment.

All chemical and physical analyses were conducted by ALS Environmental (Edmonton, Alberta), while toxicity bioassays were completed by Maxxam Analytics (Burnaby, British Columbia).

2.3 ANALYTICAL APPROACH AND DATA ANALYSIS

2.3.1 Hydrology

Continuous and manual measurement data were managed and analyzed using Hatfield's internally-operated database (Aquarius Time-Series® Version 3.10.71 software from Aquatic Informatics), to ensure data quality, consistency, and completeness. All data were published on Hatfield`s web portal website located at www.waterresourcedata.com, with secure access provided to Canadian Natural.

Data analysis and handling procedures included the processing of raw hydrometric observations, development of stage-discharge relationships, and calculation of volumes and a water balance for the Lake.

2.3.1.1 Water Level Data

Management and correction of continuous water level data were completed using procedures outlined in BC MOE (2009) and WSC (2001). Manual water level measurements recorded during each field visit were used to convert sensor-derived depth observations to geodetically-referenced elevations. The continuous records were adjusted to correct for any identified sensor drift or sensor movement. In general, corrections to water level data were applied where they differed from manually surveyed water levels by greater than 0.003 m.

2.3.1.2 Stage-Discharge Relationships

Manual discharge measurements and concurrent water levels were plotted to develop stage-discharge relationships (SDRs) for IC-1, MR-U, and OC-1. At least ten paired stage-and-discharge measurements (rating points) distributed across a range of discharges are typically required to create a reliable stage-discharge curve (BC MOE 2009). Stage-discharge curves that are developed with fewer rating points, or with measurements across a narrow range of flows, should be interpreted with caution due to the increased uncertainty of computed discharge values.

Each continuous discharge time series was calculated by inputting the continuous stage (water level) record and the SDR into the following equation:

$$X = C * (Y - a)^\wedge b$$

where X is the calculated discharge (in m^3/s), C is a rating curve constant, Y is the manually measured stage (m), a is the rating curve offset (or stage at zero flow), and b is the rating curve slope.

Corrections were applied to the available SDR model to ensure that the calculated discharges remained within 5% of the manual discharge measurements. This was accomplished by shifting the SDR to the available manual measurements. Shift corrections help to account for streambed scour or deposition processes and backwater effects on the SDR. It should be noted that the SDRs derived for the IC-1 and OC-1 stations utilize a relatively short period of record and are considered preliminary; these SDRs will be revised and refined as additional discharge measurements are collected in support of future monitoring.

HEC-RAS Hydraulic Modeling

A one-dimensional steady flow hydraulic model (HEC-RAS Version 5.0.3, developed by the U.S. Army Corps of Engineers) of the outlet channel was used to provide additional rating points to the OC-1 SDR and extrapolate for discharge levels that were not observed in 2018 but are expected to occur in the future. HEC-RAS model inputs, assumptions, and methods are described below, and qualitative assessments of each stage-discharge curve are provided in Sections 3.3 and 3.3.4. Reporting in subsequent years will incorporate a comparison of rating points derived from the HEC-RAS model and future rating points from manual stage and discharge measurements. The model operates by calculating water level elevations that would occur at discrete input discharges. Modeled water level elevations and input discharges were paired and used to contribute to the development of the OC-1 SDR because less than 10 sets of manual observations were available from this station. The model was developed by entering datum-referenced water elevations from the cross-section surveys of the outlet channel into the HEC-RAS cross-section editor. Measured cross-sections were arranged (according to downstream distance) in a HEC-RAS geometry file. Downstream distances were derived using GPS coordinates from each cross-section survey.

Inputs and assumptions of the HEC-RAS model are listed in Table 3. Input variables include a roughness coefficient (Manning's n-value), cross-section interpolation distances, and downstream boundary conditions. The roughness coefficient describes the resistance of the channel to flow (friction), and accounts for factors such as channel substrate type, instream vegetation, and embedded debris. Estimates for roughness coefficients used in the model were based on field observations and standard reference sources (Chow 1959, Barnes 1967). HEC-RAS applies roughness coefficients to both the wetted channel and the floodplain. The cross-section interpolation distance was selected based on an iterative process that allowed the model to more effectively interpolate hydraulic changes between measured cross-sections. Normal depths were selected as the downstream boundary conditions for each cross-section, due to the absence of critical flow conditions in the outlet channel. The channel friction slope was based on the overall slope of the channel, estimated from the channel bed elevations and the overall horizontal distance between the uppermost and lowermost cross-section surveys. Flow rates inputted to the model were based on flows that were assumed to naturally occur in the outlet channel, and flow rates that are expected to result in bankfull water levels. Several iterations of the model were run with slightly modified roughness coefficients for each cross-section, in order to calibrate the model. The model was calibrated such that output water levels fit closely with surface water elevations surveyed in the outlet channel.

Table 3 HEC-RAS steady flow model input data.

Model Input	Outlet Channel
Cross-section interpolation distance (m)	3
In-channel roughness coefficient	0.135
Floodplain roughness coefficient	0.135
Boundary condition	Normal depth
Channel friction slope	0.002
Flow rates modeled (m^3/s)	0.001, 0.01, 0.136, 0.3, 0.5, 1.0, 1.5, 2.0

Lake Inlet Channel

The 2017 SDR for the inlet channel was adjusted to incorporate changes resulting from inlet repairs in March 2018. This included lowering the entire SDR by approximately 0.6 m to account for channel repairs conducted by Canadian Natural. Updated as-built drawings provided by Canadian Natural confirmed the elevation change to the inlet channel. The resultant 2018 SDR was validated using sets of manual measurements collected during the May, August, and September field visits. Manual measurements collected in April, June, and October did not plot closely with the SDR, due to erosion of the inlet channel in April and backwater effects following filling of the Lake in May. SDR information, including the rating equation, is provided in Table 4. The 2018 SDR for IC-1 is also presented in Figure 3 below.

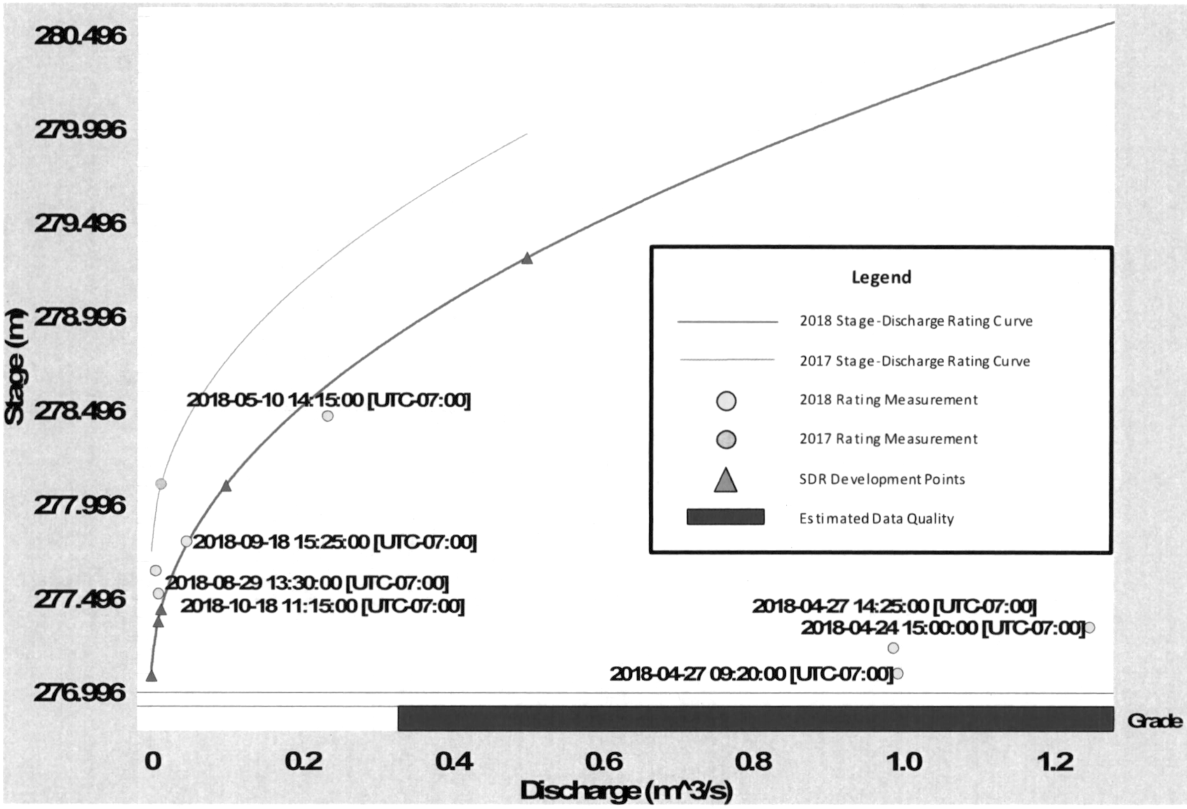
Table 4 2018 SDR date range, equation, and grades for station IC-1.

SDR ID	SDR Start Date	SDR End Date	SDR Equation[1]	Estimated Discharge Grade[2]
IC-1 - 2017	April 1, 2017	March 1, 2018	$Q = 0.081 \cdot (HG-277.66)^{2.165}$	Entire Range
IC-1 - 2018	March 1, 2018	Open-ended	$Q = 0.081 \cdot (HG-276.996)^{2.165}$	>0.33 m^3/s

[1] HG (height of gauge) refers to the water level corrected to a datum.

[2] Derived discharge data within this range will be assigned an Estimated data grade.

Figure 3 Stage discharge curve used to compute continuous discharge data for Mrs. T's Lake – Inlet Channel station (IC-1), 2018.



Muskeg River

The 2017 SDR for the upstream Muskeg River station (MR-U) was used to compute continuous discharge data in 2018. Manual measurements collected in April and May 2018 fit the curve well and were used to validate the SDR. Manual measurements collected during the June, August, September, and October field visits plotted above the SDR, which were indicative of the backwater conditions resulting from a beaver dam located approximately 200 m downstream of the station (Figure 5). SDR information, including the rating equation, are provided in Table 5. The SDR for MR-U is presented in Figure 4 and depicts the six sets of manual measurements collected in 2018.

Table 5 2018 SDR date range, equation, and grades for station MR-U.

SDR ID	SDR Start Date	SDR End Date	SDR Equation[2]	Estimated Discharge Grade[3]
MR-U - 2017	April 1, 2017	Open-ended[1]	$Q = 3.646 \cdot (HG-277.06)^{1.785}$	< 0.05 m^3/s, > 13.7 m^3/s

[1] An "open-ended" end date signifies that the SDR is expected to be valid in future years, and development of the SDR will continue with the collection of further stage and discharge measurements.

[2] HG (height of gauge) refers to water level corrected to a datum.

[3] Derived discharge data within this range will be assigned an Estimated data grade.

Figure 4 **Stage discharge curve used to compute continuous discharge data for Mrs. T's Lake – Muskeg River at Lake Inlet Channel station (MR-U), 2018.**

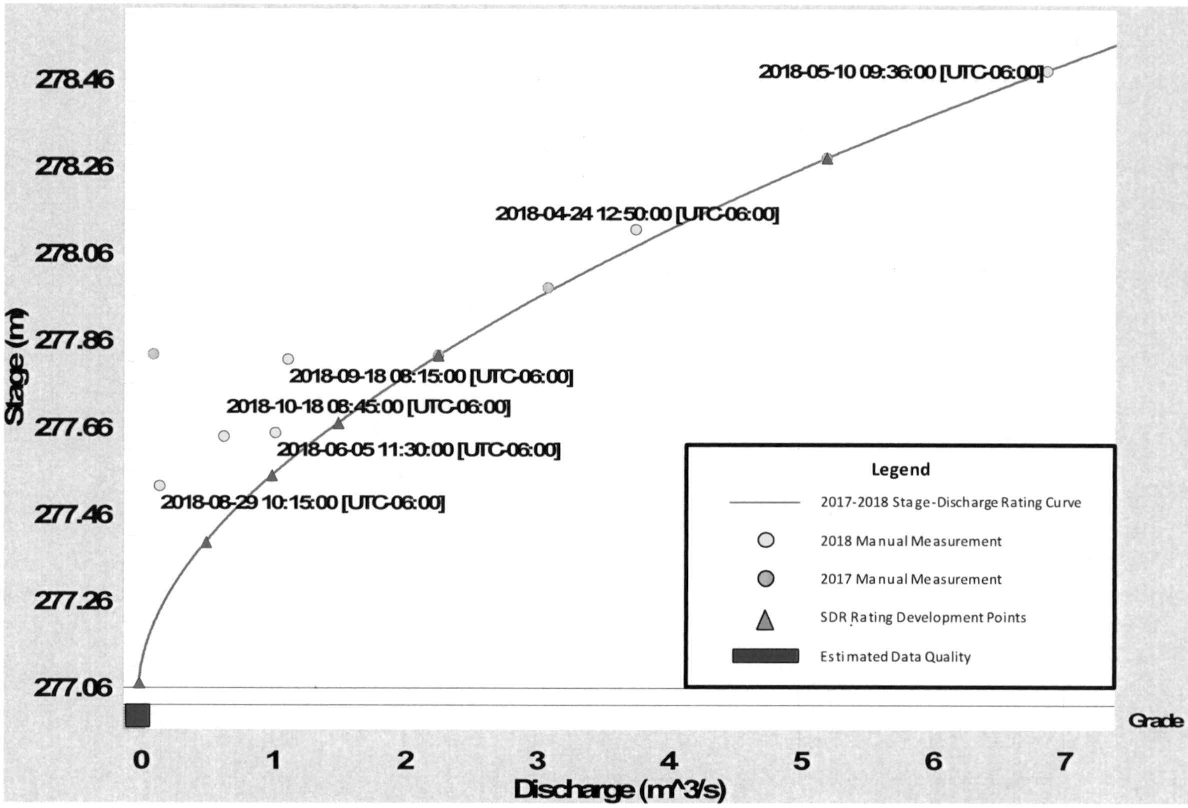


Figure 5 **Beaver dam located 200 m downstream of the Muskeg River at Lake Inlet Channel station (MR-U), June 5, 2018.**



Lake Outlet Channel

The 2018 SDR for the outlet channel was developed using a single pair of manual stage and discharge measurements, in combination with HEC-RAS steady flow model outputs (Table 6). Only one set of manual measurement was available because the outlet channel was dry during all site visits except May 10; all other rating points were estimated using the calibrated HEC-RAS model of the outlet channel.

Table 6 Stage-discharge rating points generated from the HEC-RAS model for Mrs. T's Lake outlet channel station (OC-1), 2018.

Input Discharge (m^3/s)	0.001	0.136*	0.3	0.5	1.0	1.5
Output Water Level Elevation (m)	277.99	278.41*	278.95	278.81	279.16	279.42

* These values were observed manual measurements collected during the May 10, 2018 field visit and used to calibrate the HEC-RAS model.

The SDR for OC-1 should be interpreted with caution because of limited manual measurement information and the use of the approximated model outputs. SDR information, including the rating equation, is provided in Table 7. The 2018 OC-1 SDR is also presented in Figure 6 below.

Table 7 Date range, equation, and grades for the 2018 stage-discharge curve for Mrs. T's Lake outlet channel station (OC-1), 2018.

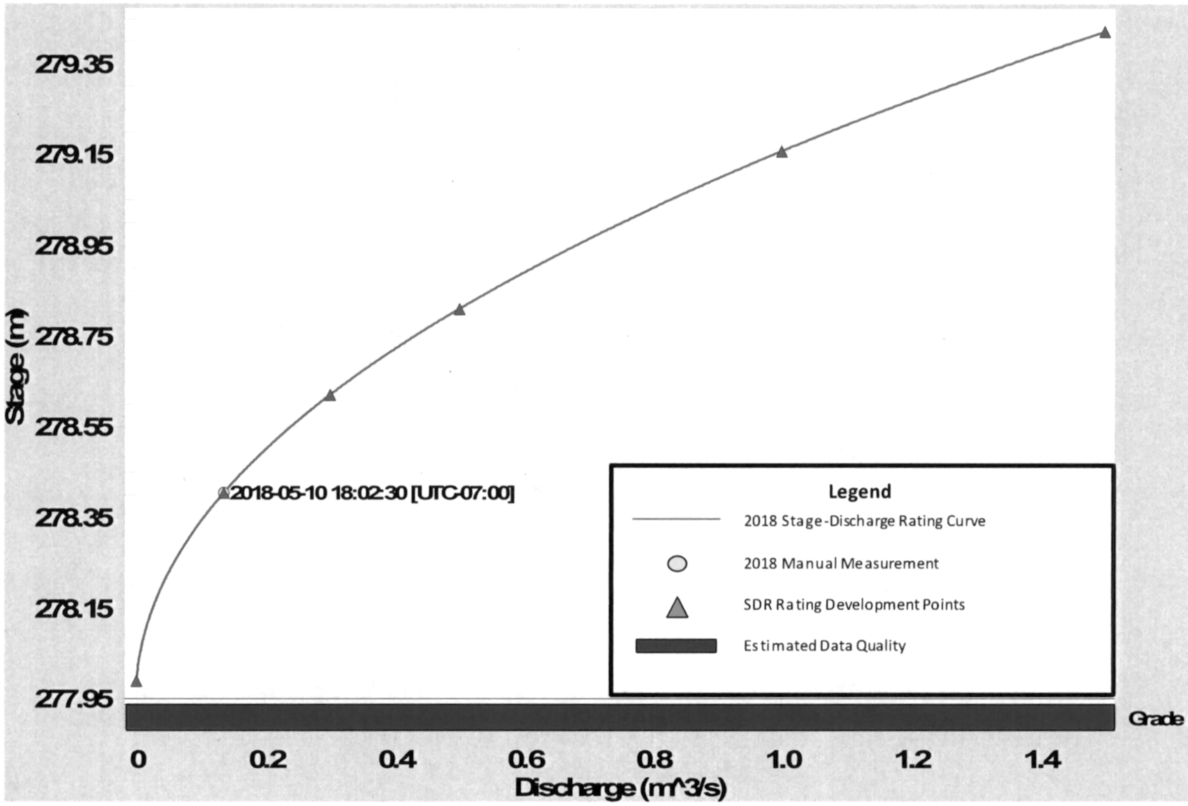
SDR ID	SDR Start Date	SDR End Date	SDR Equation[2]	Estimated Discharge Grade[3]
OC-1 - 2018	April 1, 2017	Open-ended[1]	$Q = 0.680 \cdot (HG-277.95)^{2.044}$	Entire Range

[1] An "open-ended" end date signifies that the SDR is expected to be valid in future years, and development of the SDR will continue with the collection of further stage and discharge measurements.

[2] HG (height of gauge) refers to water level corrected to a datum.

[3] Derived discharge data within this range will be assigned an Estimated data grade.

Figure 6 **Stage discharge curve used to compute continuous discharge data for Mrs. T's Lake Outlet Channel station (OC-1), 2018.**



2.3.1.3 Lake Volume Calculations

Daily Lake volumes were calculated using the bathymetry profile described in the MRME Compensation Lake Detailed Design Report (Norwest 2013), a Lake area derived from a May 6, 2018 satellite image (CNRL 2018), and the daily average water level data measured at station LL-1 in 2018. Canadian Natural collected updated bathymetry data in 2018, and this dataset will be used for future Lake volume calculations. These volumes are compared to the full operating Lake level (i.e., the 11.869 m elevation of the Outlet Channel sill) in Section 3.3.1.5. The full operating level is lower than the FSL and corresponds to the minimum Lake level that will allow spilling to the Outlet Channel will occur. The following approach was used to calculate 2018 daily and full operating volume for the Lake, which are tabulated in Appendix A2:

1. Using the Lake's depth-area relationship shown in Table 8, depth/area slopes (rise/run) between listed Lake depths were calculated, resulting in four unique linear segments for the 12.2 m Lake depth (Table 8).

2. The depth-area slope values derived in Step 1 were used to calculate surface areas corresponding to the full operating level and 2018 daily water levels for the Lake, using a rearranged slope equation where:

$$A_2 = \text{Slope} \times (D_2 - D_1)$$

3. Incremental volumes were calculated for the Lake depths listed in Table 8, using the following equation.

$$V_2 = V_1 + (A_1 \times (D_2 - D_1)) + (A_2 - A_1) \times (D_2 - D_1) / 2)$$

Where:

V_1 = Lake volume at preceding depth listed in Table 8 (m^3);

A_1 = Lake area at preceding depth listed in Table 8 (m^2);

D_1 = Preceding Lake depth listed in Table 8 (m);

V_2 = Lake volume at succeeding depth (m^3);

A_2 = Lake area at succeeding depth (m^2);

D_2 = Succeeding Lake depth from surface (m);

4. Areas calculated in Step 2 and areas and depths from Table 8 were inputted to the incremental volume equation to calculate 2018 daily volumes and the full operating volume of the Lake.

Table 8 Approximate depth-area relationship (bathymetry) for Mrs. T's Lake, 2018.

Lake depth from bottom (m)	Lake Area (m^2)	Segment Slope
12.46*	427,110	
12.2	414,400	27,900
11.2	386,500	
		125,300
10.2	261,200	
9.2	233,000	
8.2	211,000	
7.2	190,500	
6.2	171,600	
5.2	153,000	18,930
4.2	135,200	
3.2	117,800	
2.2	101,500	
1.2	87,500	
0.2	71,900	
		15,500
0.0	68,000	

* Maximum Lake depth was derived from LL-1 daily average water elevation data and the associated Lake area was derived from a May 6, 2018 Geoeye-1 image (50-cm resolution) of the Lake. All other lake depths and areas were derived from the detailed design of the Lake (Norwest 2013).

2.3.1.4 Lake Water Balance

A volumetric water balance was calculated to quantify inputs and outputs from the Lake, to assess hydrologic functionality of the Lake. The water balance was calculated on a daily basis using the equation described in Hood (2006) where:

$$IG - OG = \Delta V/\Delta t - P + E - Is + Os$$

The water balance components and data sources for this equation are described in Table 9.

Table 9 MRME Compensation Lake water balance component data sources.

Component	Description	Data Source	Location	Operator
IG-OG	Groundwater Residual (Groundwater inputs – Groundwater outputs)	Calculated (Unmeasured)	N/A	N/A
$\Delta V/\Delta t$	Lake storage change	LL1 Water Level Station	MRME	Canadian Natural
P	Precipitation	C1 Climate Station	Jackpine Mine	JOSMP (AEP)
E	Evaporation	Morton Method evaporation data (AESRD, 2013)[1]	Fort McMurray	(AESRD 2013)
I_s	Surface water inflows	IC-1 Hydrometric Station	MRME	Canadian Natural
O_s	Surface water outflows	OC-1 Hydrometric Station	MRME	Canadian Natural

[1] Evaporation data were derived by averaging monthly Morton Method values from 1972-2009 for the Environment Canada Fort McMurray Climate Station and disaggregating monthly values to daily by dividing by the number of days in each month.

The residual component of the water balance represents the water that is not accounted for by the known measured and calculated values and is assumed to be dominated by groundwater and subsurface flows. A positive residual value indicates the Lake gained water from unmeasured inputs and a negative residual value is indicative of water losses to an unmeasured output.

2.3.1.5 Water Temperature Data

Management and correction of continuous water temperature data was completed for stations MR-U, MR-D, IC-1, OC-1, and LL-1. Processing of water temperature data included identifying data gaps and anomalous data values or patterns, and if necessary, removing these data from the record. Daily mean water temperature data are provided in Appendix A2.

2.3.2 Water Quality

2.3.2.1 Continuous Water Quality

Data from water temperature loggers were plotted into a depth-integrated time-series graph using SigmaPlot 12.5. Continuous time trend graphs of the continuous water quality measurements have been presented in graphical format and screened against relevant guidelines, where applicable.

2.3.2.2 In Situ and Limnological Water Quality

Monthly in situ water quality depth profiles are presented graphically and in tabular format to assess temporal and spatial variation within the Lake, and to confirm stratification trends observed in the continuous water quality dataset.

2.3.2.3 Analytical Water Quality

All water quality samples collected in 2018 were analyzed for conventional variables, major ions, nutrients, organic compounds, and total and dissolved metals. A complete list of water quality analytes is provided in Table 10.

A sub-set of the 66 water quality variables that were measured from Mrs. T's Lake during the summer (July 24) and fall (September 13) sampling programs was selected for discussion in this report; these variables of interest are consistent with measurement endpoints used to assess productivity and environmental quality in other Canadian Natural compensation lakes, as well JOSMP assessments of regional water quality, and include:

- pH – an indicator of acidity;
- Conductivity – basic indicator of overall ion concentration;
- Total suspended solids (TSS) – a variable strongly associated with several other measured water quality variables, including total phosphorus, total aluminum, and numerous other metals;
- Dissolved phosphorous, total nitrogen, and nitrate+nitrite – indicators of nutrient status. Dissolved phosphorus rather than total phosphorus is included because it is the primary biologically-available species of phosphorus and because total phosphorus levels are strongly associated with TSS;

- Major ions (sodium, chloride, sulphate, calcium, magnesium) – indicators of ion balance, which could be affected by discharges or seepages from oil sands development or by changes in water table and changes in the relative influence of groundwater;
- Total alkalinity – an indicator of the buffering capacity and acid sensitivity of waters;
- Total dissolved solids (TDS) and dissolved organic carbon (DOC) – indicators of total ion concentrations and dissolved organic matter (particularly humic acids), respectively;
- Total and dissolved aluminum – as a variable of interest in some oil sands EIAs, by CEMA, and in the RAMP 5-year report (Table 3.2-1). Total aluminum, for which water quality guidelines exist, has been demonstrated to be strongly associated with TSS (Golder 2003). Dissolved aluminum more accurately represents biologically available forms of aluminum that may be toxic to aquatic organisms (Butcher 2001);
- Total boron, total molybdenum, total strontium – three metals found in predominantly-dissolved form in waters of the Athabasca oil sands region (RAMP 2005), and may be indicators of groundwater influence in surface waters;
- Total arsenic and total mercury – metals of potential importance to the health of aquatic life and human health; and
- Naphthenic acids – relatively-labile hydrocarbons associated with oil sands deposits and processing that have been identified as a potential toxicity concern.

All water quality results were compared against relevant guidelines for the protection of aquatic life, including the Environmental Quality Guidelines for Alberta Surface Waters (GoA 2018). A Piper plot diagram was also used to illustrate the relative ion concentrations in the Lake and the outlet channel.

The compiled 2018 water quality data are presented in Section 3.3.2, and the reports from the analytical laboratories are provided in Appendix A3.

Table 10 Water quality variables measured in Mrs. T's Lake, summer and fall 2018.

Group	Water Quality Variable	
Conventional Variables	True Colour	Total dissolved solids
	Dissolved organic carbon	Total hardness
	pH	Total organic carbon
	Specific conductance	Total suspended solids
	Total alkalinity	Biological oxygen demand
Major Ions	Bicarbonate	Magnesium
	Calcium	Potassium
	Carbonate	Sodium
	Chloride	Sulphate
	Hydroxide	Sulphides
Nutrients	Nitrate+nitrite	Phosphorus – total
	Ammonia nitrogen	Phosphorus – dissolved
	Total Kjeldahl nitrogen	Ortho-phosphate
	Chlorophyll-a	Nitrate
	Total nitrogen	Nitrite
Organics	Naphthenic acids	Oil sands acid extractables
	Total phenolics	Total recoverable hydrocarbons
Total and Dissolved Metals	Aluminum (Al)	Manganese (Mn)
	Antimony (Sb)	Mercury (Hg)
	Arsenic (As)	Mercury (Hg) – ultra trace[1]
	Barium (Ba)	Molybdenum (Mo)
	Beryllium (Be)	Molybdenum (Mo) – low detection[2]
	Bismuth (Bi)	Nickel (Ni)
	Boron (B)	Selenium (Se)
	Cadmium (Cd)	Silver (Ag)
	Calcium (Ca)	Strontium (Sr)
	Chlorine (Cl)	Thallium (Tl)
	Chromium (Cr)	Thorium (Th)
	Cobalt (Co)	Tin (Sn)
	Copper (Cu)	Titanium (Ti)
	Iron (Fe)	Uranium (U)
	Lead (Pb)	Vanadium (V)
	Lithium (Li)	Zinc (Zn)

[1] Total mercury (Hg) measured with an ultra-trace detection limit of 0.08 ng/L.

[2] Total molybdenum (Mo) measured with a low detection limit of 0.00005 mg/L.

2.3.2.4 Trophic Status

Trophic status measures the degree of biological production within a lake. Trophic status of Mrs. T's Lake was evaluated using the production-based trophic state index (TSI) presented in Wetzel (2001), where:

$$TSI = 14.42 \ln (\text{Total Phosphorus } [mg/m^3]) + 4.15$$

Total phosphorus concentrations were reported in mg/L concentrations, which were converted to mg/m^3 by multiplying the result by a factor of 1,000. In general, lakes with TSI values <40 are representative of oligotrophic conditions, 41-50 suggest mesotrophic conditions, 51-70 indicate eutrophic conditions, and values above 70 represent hypereutrophic conditions (Wetzel 2001).

Phosphorus (P) and nitrogen (N) are known to be the primary nutrients that influence the growth and biomass of primary productivity in freshwater ecosystems (Wetzel 2001). The molar ratio of total N to total P in water was used to estimate the relative supplies of N and P available to support algal growth in the Lake. A molar N:P ratio below 20 is often indicative of N-limitations on algal growth, whereas P-deficient conditions are prevalent at molar N:P ratios greater than 50 (Guildford and Hecky 2000). At intermediate ratios (20-50), either of the two nutrients can be limiting.

2.3.3 Sediment Quality

Lake sediments were collected during the August field program and analyzed for particle size, moisture content, carbon content, total metals, organics, and target and alkylated PAHs (Table 11). Sample results were compared against CCME interim sediment quality guidelines (ISQG), which represent the concentration below which adverse biological effects to aquatic biota rarely occur, and probable effects levels (PEL), which represent the concentration that is expected to cause adverse effects to aquatic biota (GoA 2018; CCME 2011). The compiled 2018 sediment quality data are presented in Section 3.3.3, and the reports from the analytical laboratories are provided in Appendix A4.

Table 11 Sediment quality variables measured in Mrs. T's Lake, August 2018.

Group	Sediment Quality Variable		
Physical variables	Percent sand	Texture	Moisture content
	Percent silt	Percent clay	
Carbon content	Total inorganic carbon	Total organic carbon	Total carbon by combustion
Total metals	Aluminum	Iron	Selenium
	Antimony	Lead	Silver
	Arsenic	Lithium	Sodium
	Barium	Magnesium	Strontium
	Beryllium	Manganese	Thallium
	Bismuth	Mercury	Tin
	Cadmium	Molybdenum	Titanium
	Calcium	Nickel	Uranium
	Chromium	Phosphorus	Vanadium
	Cobalt	Potassium	Zinc
	Copper		
Organics	BTEX (Benzene, Toluene, Ethylene, Xylene)		
	CCME 4-fraction total hydrocarbons:	- F2 (C10-C16)	- F4 (C34-C50)
	- F1 (C6-C10)	- F3 (C16-C34)	- Total hydrocarbons (C6-C50)
Target PAHs	Acenaphthene	Benzo(g,h,i)perylene	Fluorene
	Acenaphthylene	Biphenyl	Indeno(c,d-123)pyrene
	Anthracene	Dibenzo(a,h)anthracene	Naphthalene
	Benzo(a)anthracene	Dibenzothiophene	Phenanthrene
	Benzo(a)pyrene	Fluoranthene	Pyrene
	Benzo (b,j,k) fluoranthene		
Alkylated PAHs	C1-substituted acenaphthene	C3-substituted dibenzothiophene	C2-substituted naphthalenes
	C1-substituted benzo(a)anthracene/chrysene	C4-substituted dibenzothiophene	C3-substituted naphthalenes
	C2-substituted benzo(a)anthracene/chrysene	C1-substituted fluoranthene/pyrene	C4-substituted naphthalenes
	C1-substituted biphenyl	C2-substituted fluoranthene/pyrene	C1-substituted phenanthrene/anthracene
	C2-substituted biphenyl	C3-substituted fluoranthene/pyrene	C2-substituted phenanthrene/anthracene
	C1-substituted benzofluoranthene/ benzo(a)pyrene[1]	C1-substituted fluorene	C3-substituted phenanthrene/anthracene
	C2-substituted benzofluoranthene/benzo(a)pyrene[1]	C2-substituted fluorene	C4-substituted phenanthrene/anthracene
	C1-substituted dibenzothiophene	C3-substituted fluorene	1-methyl-7-isopropyl-phenanthrene (retene)[2]
	C2-substituted dibenzothiophene	C1-substituted naphthalenes	
Sublethal toxicity testing	Survival and growth of the amphipod *Hyalella azteca*		
	Survival and growth of *Chironomus dilutus* midge larvae		

[1] Concentration not included in calculation for estimation of PAH toxicity in sediments (Neff et al 2004).

[2] Any summations of total PAHs did not include retene, as it is also accounted for in total C4-substituted phenanthrene/anthracene.

2.3.3.1 PAH Toxicity in Sediments

Estimation of PAH toxicity in Mrs. T's Lake sediments was conducted using the Neff et al. method (2004), which incorporates 41 individual PAH compounds into the calculation. The Neff method (described below) requires that each individual PAH measurement first be normalized to a measure of total recoverable hydrocarbons to produce an estimate of the combined PAH concentration that is available. PAH bioavailability (i.e., potential toxicity) in sediments is affected by the concentration of organic matter (USEPA 2003); if sediment organic carbon is high, then PAH compounds are more likely to stay partitioned in the sediments and are less available to organisms. The characteristics of the sediment organic material also affects the partitioning of PAH compounds. Petrogenic PAH, such as the alkylated PAH found in the Athabasca oil sands region, have a high affinity for non-aqueous phase liquids (NAPL). This affinity drives the partitioning of PAH between the three sediment phases of porewater, sediment organic material, and NAPL, and therefore affects the availability of PAH to organisms. Normalizing for this affinity for NAPL is important because other methods, such as those described by the US Environmental Protection Agency (USEPA 2003), rely on concentrations of total organic carbon to normalize PAH concentrations in the hazard index calculation. The Neff method is also preferable because it incorporates more individual PAH compounds into the PAH toxicity calculation (41 individual compounds) than the USEPA method (13, 23, or 34 depending on variation), thereby providing a more accurate representation of potential PAH toxicity.

Values for PAH concentrations and total CCME hydrocarbons (used to estimate total recoverable hydrocarbons) were obtained through laboratory analysis.

$$PAH_{(normalized)} = \frac{PAH\ concentration}{total\ recoverable\ hydrocarbons}$$

Where:

- $PAH_{(normalized)}$ refers to the estimate of PAHs available in porewater and complexed to the organic fraction of sediment particles; and
- Total recoverable hydrocarbons are estimated by the equation:

$$Total\ recoverable\ hydrocarbons = total\ CCME\ hydrocarbons * 2.183$$

Normalized PAH concentrations are divided by a K_{ow} partition coefficient, thereby removing the portion of PAHs complexed to sediments and estimating the concentration available in porewater alone; this provides the bioavailable amount of each PAH. The porewater estimate is further divided by a chronic toxicity value for water (Mackay et al 1992, Neff and Burns 1996, and Ran et al 2002, as cited in Neff et al 2004) to produce a hazard quotient (HQ) for each PAH measured in the sediment sample:

$$HQ = \left(\frac{PAH_{(normalized)}}{K_{ow}}\right) \div Chronic\ Toxicity\ value$$

The hazard quotients are then summed to produce a hazard index (HI) for total PAHs in sediment porewater.

2.3.3.2 Sediment Toxicity

Sublethal (chronic) toxicity testing provides an effects-based assessment of sediment quality by comparing the survival and growth of test organisms exposed to lake sediments against the responses of test organisms exposed to laboratory-supplied control sediments (Environment Canada 1997, 2013). Toxicity bioassays included:

- 14-day static tests for survival and growth in sediment using a freshwater amphipod (*Hyalella azteca*) (Environment Canada 2013); and
- Ten-day static tests for survival and growth in sediment using the larvae of freshwater midges (*Chironomus dilutes*) (Environment Canada 1997).

A magnitude difference of >20% between any test and control group endpoint was considered ecologically significant (CCME 1995). Test results were displayed using the statistical package R (www.r-project.org).

3.0 RESULTS AND DISCUSSION

3.1 QUALITY ASSURANCE AND QUALITY CONTROL

A variety of quality control procedures were applied during the 2018 program, with the objective of providing incremental checks and balances throughout data collection, data analysis, and reporting. Detailed descriptions of the QA/QC procedures specific to each sampling task are provided in Appendix A1, with results summarized below.

The following dissolved metals: calcium, magnesium, potassium, sodium, iron, and manganese, were analyzed using inductively coupled plasma mass spectrometry (ICPMS) in summer and inductively coupled plasma-optical emission spectroscopy (ICPOES) in fall. Detection limits between the two methods differ for calcium iron and manganese. Despite the variation in methods, none of the analytes were below detection limits and the summer and fall results were included in the analysis of results. No analytes exceeded the QA/QC guideline of 5 times the method detection limit for water quality field blanks and trip blanks collected during summer and fall. For duplicate samples, analytes exceeding the QA/QC guideline of a >20 relative percent difference (RPD) at concentrations >5-times the detection limit were limited to total dissolved phosphorus in summer and dissolved manganese in fall; there are no water quality guidelines for either of these analytes. RPDs >20% were observed for naphthenic acids and phenols in the fall duplicate samples, but absolute concentrations were less than 5-times the detection limit. Overall, these results confirm that the water quality measurements were of acceptable quality and adequate to address the objectives of this study.

Total chlorine was non-detectable in all summer and fall samples from Mrs. T's Lake; however, the laboratory detection limit (0.1 mg/L) was above the GoA (2018) guideline of 0.0005 mg/L. The quality control report from the lab indicated that the actual hold time for total chlorine samples in summer and fall (ranging from 19 to 26 hours) exceeded the ALS recommended hold time of 0.25 hours. The laboratory recommends a field measurement for accurate characterization of total chlorine concentrations, but this is not considered necessary to fulfill the monitoring obligations of the Program. The quality control report from the lab also indicated that the recommended 28-day hold time for recoverable hydrocarbons was exceeded by two days for the summer sampling event, despite receiving the samples well in advance from Hatfield; all recoverable hydrocarbon concentrations were below the 1 mg/L detection limit in 2018, indicating the holding time exceedance did not have a substantive effect on the data quality for this analyte.

One sediment quality split sample was collected from PZ-1 in 2018. Analytes with RPDs greater than 20% and concentrations greater than five times the detection limit included titanium and 4-Bromofluorobenzene; neither of these variables have sediment quality guidelines. Overall, these results confirm that the 2018 sediment dataset was of acceptable quality and adequate to address the objectives of this study.

Potential sources of contamination were not apparent as field crews adhered to protocols and procedures for the collection of water and sediment samples. Results of field blank, trip blank, and duplicate and split samples indicated that contamination associated with sample collections was unlikely. Internal QA/QC results from ALS Laboratories also did not identify any obvious contamination issues.

3.2 REGIONAL CONTEXT

3.2.1 Climate

Regional climate characteristics provide context for interpreting hydrologic patterns. The climate characterization provided below includes a summary of 2018 monthly precipitation, snow depths, and air temperatures recorded at the JOSMP – Aurora Climate Station (C1) and compares these results to the station's seventeen-year historical record (1988-1989 and 2003-2017). C1 is located approximately 4 km southeast of the Lake, and climatic conditions at this location are considered to provide a close approximation to those at the Lake.

A summary of 2018 WY and historical precipitation and snow depth data is provided in Table 12. Total precipitation for the 2018 WY was 418.2 mm, which was 15% higher than the seventeen-year historical average recorded at C1. Early winter precipitation (snowfall) was above the historical mean for the first two months, then dropped below the average for the remainder of the winter. Month-end snow depths were above the historical averages for all months, with the snowpack persisting into April. Lower than normal rainfall was recorded in the early spring, followed by a higher than average June and July, and then falling below average for the remainder of the WY. Maximum daily precipitation was lower than the historical maximums for every month of the 2018 WY, except for November, when high 24-hour snowfalls occurred (Table 12).

Table 12 2018 and historical monthly precipitation and month-end snow depths measured at the C1 Climate Station.

Month	Monthly Total Precipitation (mm)		Maximum Daily Precipitation (mm)		Month-end Snow Depth (cm)	
	2018 WY	Historical Mean	2018 WY	Historical	2018 WY	Historical
November	62.5	11.9	32.8	8.8	71.6	14.1
December	28.0	14.7	11.7	17.6	47.1	24.6
January	11.2	12.3	4.1	16.6	53.2	35.2
February	2.3	12.0	1.3	12.7	51.1	42.7
March	10.0	17.1	3.2	21.6	49.1	30.9
April	4.5	15.5	2.7	24.5	-	-
May	9.0	32.0	3.5	28.6	-	-
June	95.5	56.2	27.6	41.9	-	-
July	119.6	73.9	38.2	56.8	-	-
August	39.6	52.0	12.8	29.9	-	-
September	31.8	44.8	16.0	35.9	-	-
October	4.2	22.2	2.4	19.4	-	-
Annual Total	418.2	364.6	-	-	-	-

Maximum monthly air temperatures in all months except November were the warmest on record, and minimum monthly air temperatures in all months except May were the coldest on record, relative to the seventeen-year climate record for C1 (Table 13). The low minimum and mean air temperatures in April likely contributed to the late April snowpack melt, with a mean monthly 3.4°C cooler than the historical average for that month. Temperatures increased significantly in May, with a mean temperature 4°C warmer than the historical average. Mean temperatures for summer months (June to August) were generally similar to historical monthly means, while fall months (September-October) were cooler than average. The higher maximum air temperatures may have allowed for higher than normal evaporation from surface waters during the open-water portion of the 2018 WY.

Table 13 2018 and historical mean, maximum, and minimum monthly air temperatures measured at the C1 Climate Station.

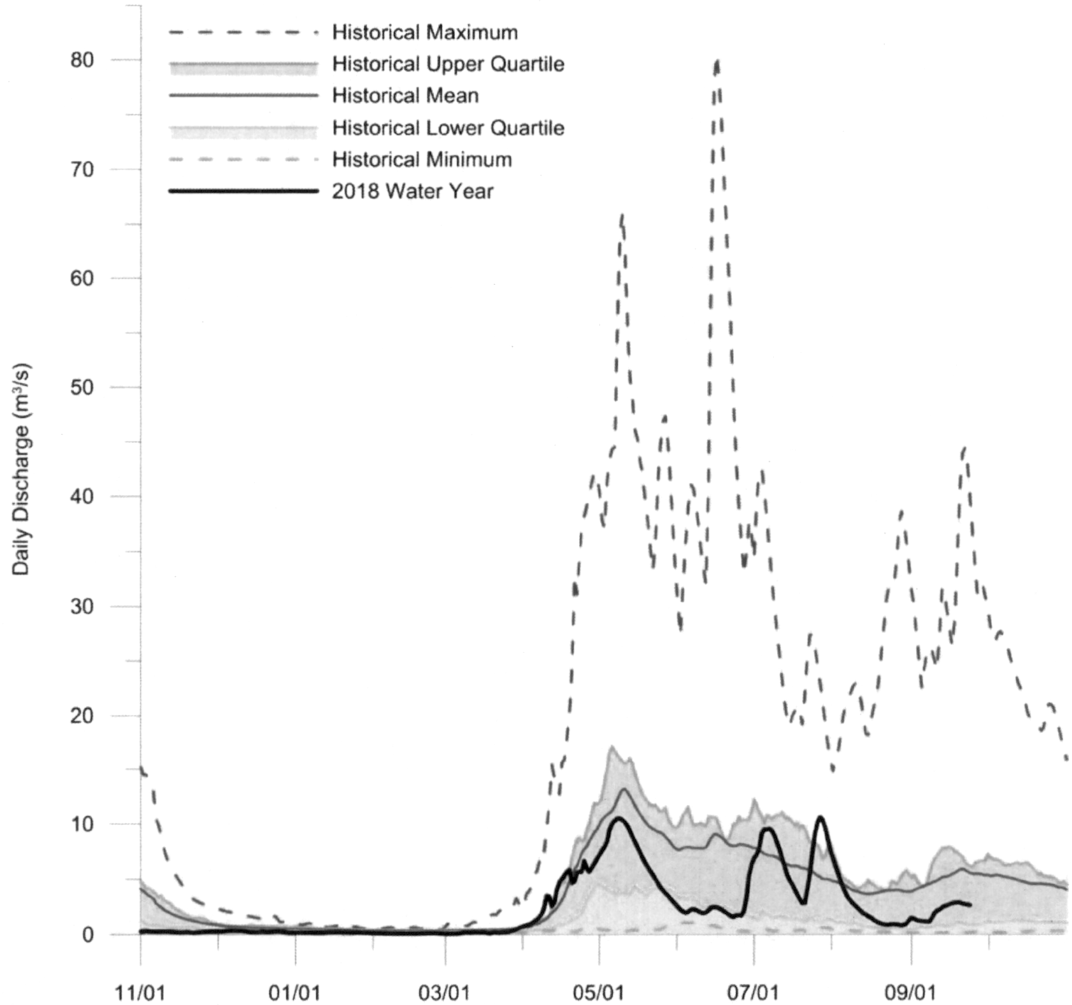
Month	Mean Monthly Air Temperature (°C)		Maximum Monthly Air Temperature (°C)		Minimum Monthly Air Temperature (°C)	
	2018 WY	Historical	2018 WY	Historical	2018 WY	Historical
November	-12.1	-7.3	-5.0	-0.4	-18.5	-14.9
December	-14.9	-15.2	-0.6	-6.4	-35.1	-23.4
January	-17.4	-17.2	-3.3	-9.8	-31.9	-27.0
February	-16.8	-12.8	-1.8	-2.0	-31.5	-19.5
March	-7.8	-7.4	2.8	-0.7	-21.2	-15.3
April	-0.2	3.2	12.7	10.7	-16.4	-3.2
May	14.4	10.6	24.3	13.8	7.1	6.6
June	16.1	15.9	28.0	18.6	6.8	12.6
July	17.9	18.1	22.7	21.6	12.1	15.0
August	15.7	15.9	22.5	17.8	7.3	13.0
September	4.1	10.3	10.4	14.1	-0.6	7.8
October	0.4	2.5	8.0	5.8	-6.4	-2.3
Annual	0.0	1.4	28.0	21.6	-35.1	-27.0

3.2.2 Hydrology

Daily discharge data from Water Survey of Canada hydrometric station 07DA008 – Muskeg River near Fort MacKay (ECCC 2018) were used to characterize the 2018 WY and the historical hydrology of the watershed that surrounds the Lake. 07DA008 is an active station measuring water level and discharge on the Muskeg River, has a relatively long data record (45 years, 1974-present), and is located approximately 10 km downstream of the Lake (see Figure 1). 2018 WY daily discharge data were only available from November 1, 2017 to September 23, 2018.

The 2018 WY was characterized by relatively low flows (see Figure 7), with discharges remaining below the historical daily averages in all months except April and July; a high snowpack persisted into late-April (Table 12), which contributed to an initial spring freshet flood that exceeded the historical upper quartile, and two rainfall events in July temporarily increased streamflows above the historical daily averages. Fluctuating flows during the 2018 WY may be attributed to higher than average precipitation and snow accumulations, paired with higher than normal air temperatures (Table 9). The 2018 WY maximum discharge at the WSC station on Muskeg River occurred in late July and measured 10.6 m^3/s, while minimums of 0.07 m^3/s were observed in early February.

Figure 7 WSC 07DA008 Muskeg River near Fort MacKay 2018 and historical mean daily discharge and historical discharge statistics.



Note: historical data series were calculated using data from 1974 to 2017.

3.3 MRS. T'S LAKE

3.3.1 Hydrology

3.3.1.1 Muskeg River Water Levels and Discharge

The hydrometric monitoring network for the Lake includes two stations on the Muskeg River: station MR-U, located directly upstream of the Lake inlet channel; and station MR-D, located directly upstream of the Lake outlet channel. The purpose of the MR-U station is to assess the availability of flow for diversion to the inlet channel and to measure Muskeg River flow reductions between the Lake inlet and outlet. The MR-D station is intended to measure any backwater effects on the outlet channel. The recorded water levels and discharges for these stations are presented and discussed below.

Water level patterns at MR-U and MR-D correlated well in 2018 (Figure 8), which suggest that discharge patterns (magnitude and timing) were also highly correlated between these two locations. The water level patterns did exhibit some slight differences, as illustrated by the small peaks observed at both stations in April and September (Figure 8); these variations were the result of backwatering caused by large amounts of in-channel vegetation (Figure 9), and a large beaver dam located approximately 200 m downstream of the MR-U station (Figure 5). The presence of the beaver dam downstream of MR-U caused a different backwater effect to occur relative to MR-D, resulting in slightly different water level response patterns. Daily water level data for MR-U and MR-D are provided in Appendix A2.

Figure 8 Daily water levels recorded at the upstream (MR-U) and downstream (MR-D) Muskeg River hydrology stations through the 2018 Water-Year.

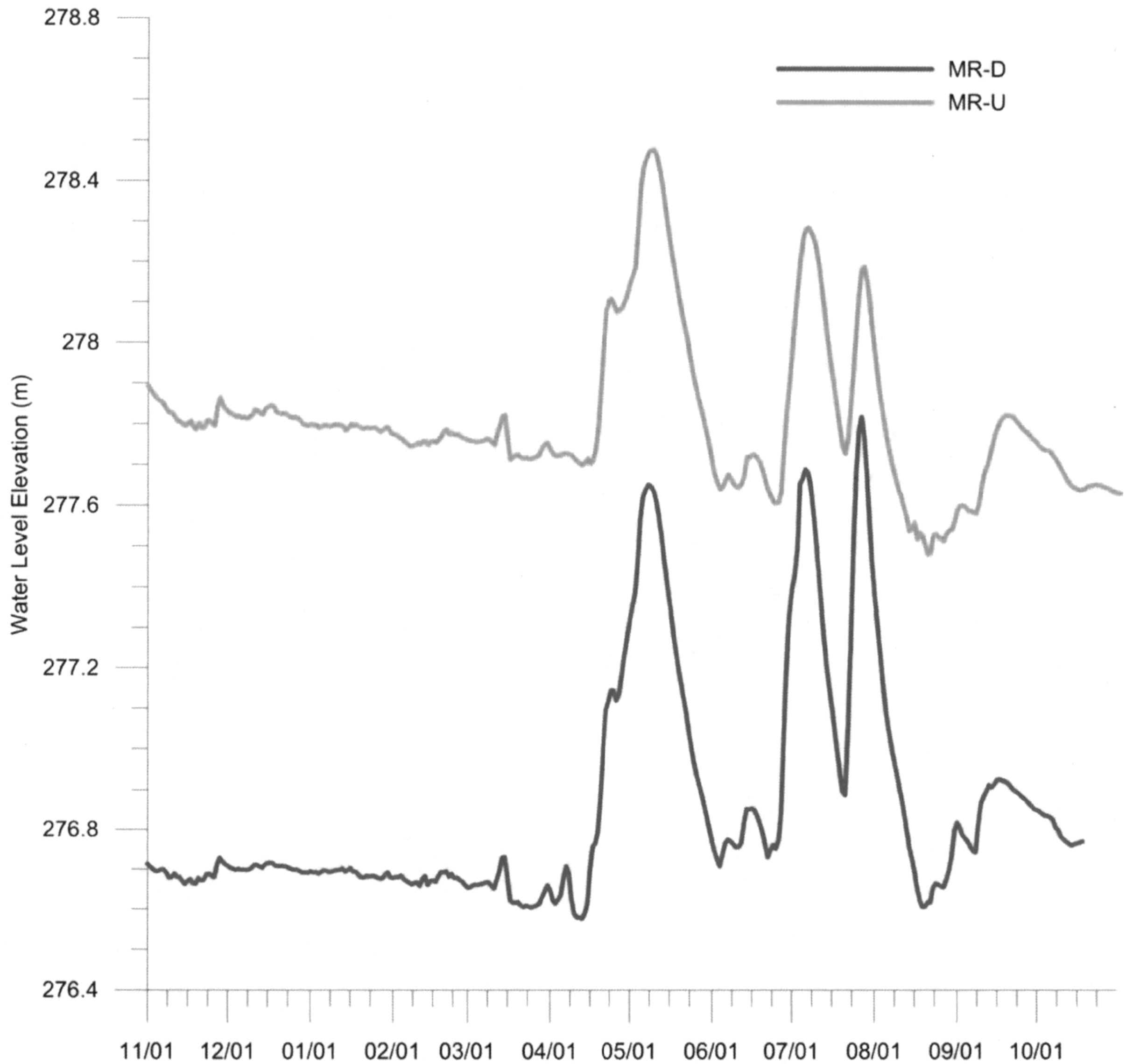
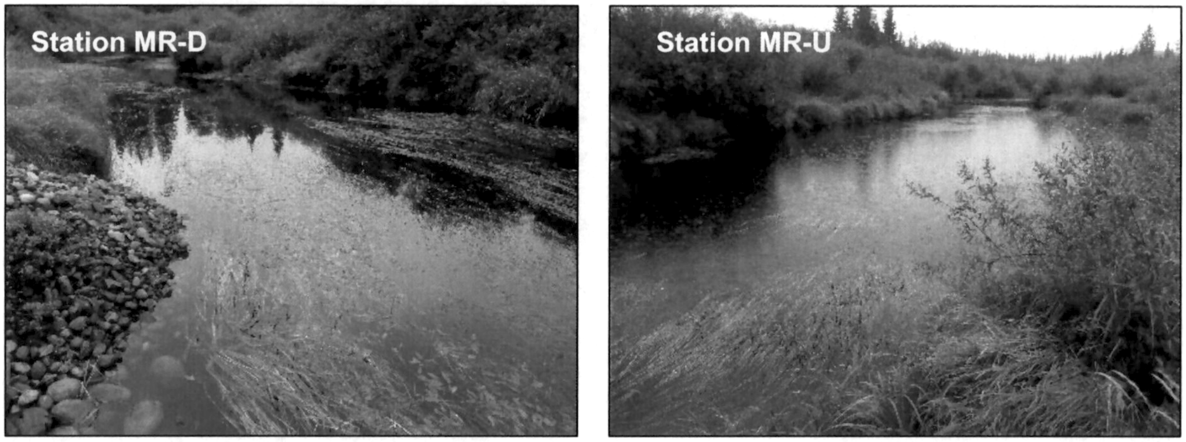
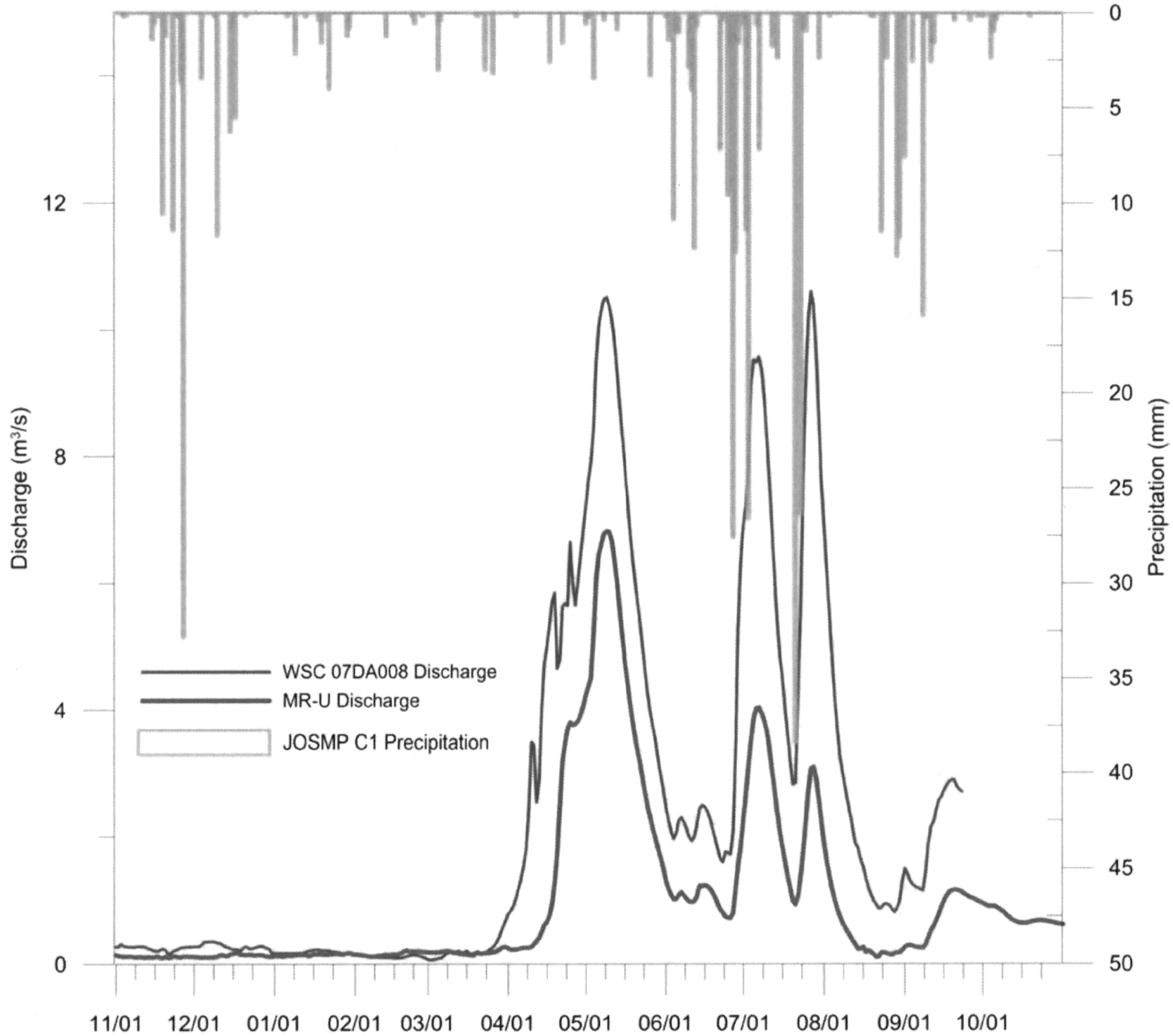


Figure 9 In-channel vegetation near the downstream (MR-D) and upstream (MR-U) Muskeg River hydrology stations, 2018.



Continuous discharge data were derived for the period extending from November 1, 2017 to October 31, 2018 (i.e., the 2018 WY). Six manual discharge measurements were collected at MR-U in 2018 (April, May, June, August, September, and October). The 2018 daily discharge data for MR-U (Figure 10, Appendix A1) shows very similar timing patterns to WSC station 07DA008. The falling limb of spring freshet was recorded in mid-May, followed by two larger rainfall-induced floods in July. Low flows began in early August and continued until the end of the water year, with small hydrologic responses to rainfall events observed in September and October. A maximum daily discharge of 6.82 m^3/s occurred at MR-U on May 9, 2018, while a minimum daily discharge of 0.1 m^3/s occurred on November 19, 2017. The strong relationship between discharge patterns at MR-U and 07DA008 suggests that 2018 was also a drier than normal year at MR-U, and that MR-U discharges likely were below average for each month of the open-water season. Bankfull flow at MR-U was not observed in 2018, which is estimated to occur at approximately 10 m^3/s (Hatfield 2017).

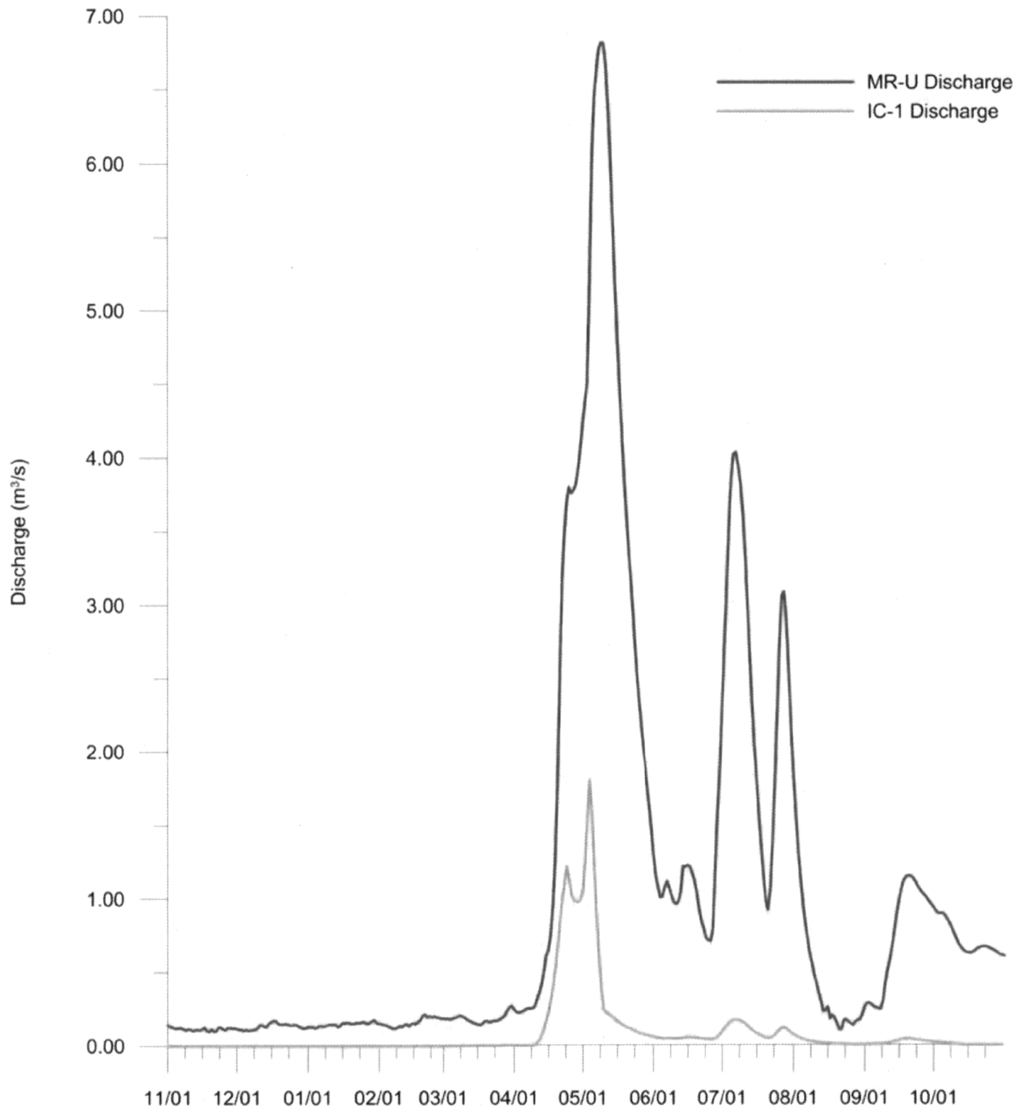
Figure 10 Muskeg River daily discharge at the upper Muskeg River (MR-U) and Environment Canada (07DA008) stations and C1 daily precipitation, 2018 WY.



3.3.1.2 Inlet Channel

Continuous water level data from the Lake Inlet Channel station (IC-1) were inputted to the SDR to produce a continuous discharge record for the 2018 WY. Seven pairs of manual water level and discharge measurements were collected from IC-1 in 2018. No flow was recorded in the inlet channel for most of the winter months, with minor under-ice flow first observed on March 18, 2018. Water levels in the Muskeg River began to increase the first week of April, and ice cover withdrew and open channel flows in the inlet channel began on approximately April 14, 2018 (see Figure 11). A maximum instantaneous discharge of 1.87 m^3/s occurred on May 4, 2018. This is in contrast to the timing of peak discharge observed at the MR-U station (May 9, 2018), which indicates that backwater effects from the Lake may have decreased flow rates in the inlet channel. Inlet channel flows began receding in mid-May and remaining at or below 0.05 m^3/s through the remainder of the 2018 WY, with the exception of two rain-induced increases in July. A rainfall event in September also resulted in a small flood response in the inlet channel.

Figure 11 Daily discharge recorded at the upper Muskeg River (MR-U) and Inlet Channel (IC-1) stations during the 2018 WY.



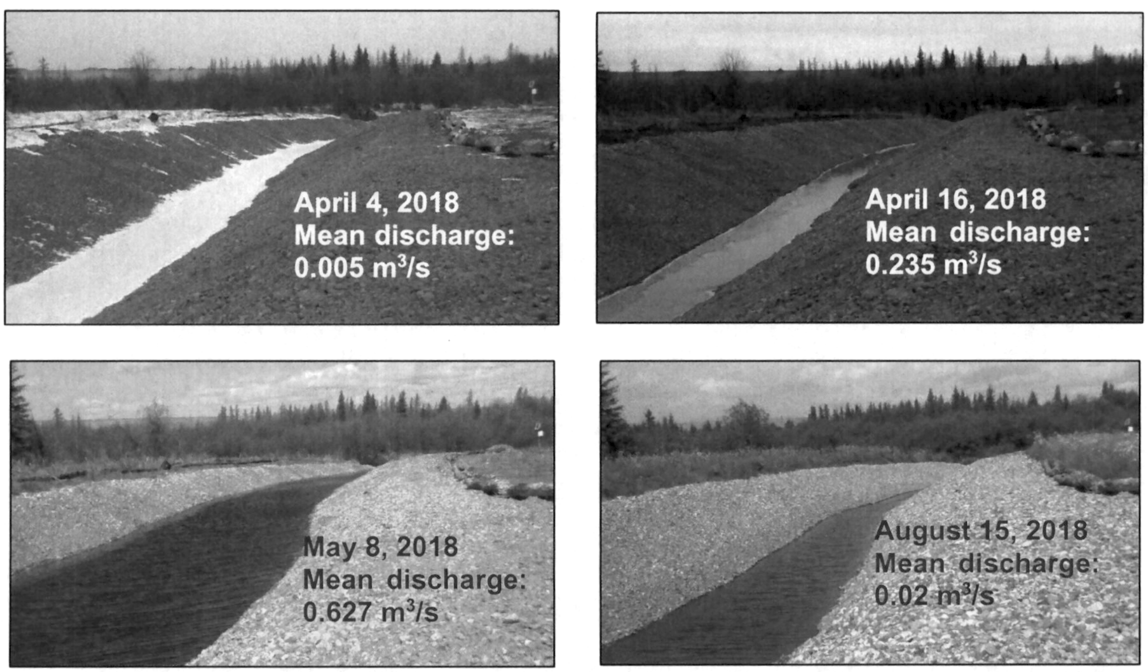
Discharges measured in the inlet channel during the April 27, 2018 field visit suggest that a portion of the surface water diverted from Muskeg River may be flowing through or beneath the substrate in the upper section of the inlet channel. Discharges were measured at the IC-1 hydrometric station (downstream), the Inlet Invert (upstream), and mid-way between IC-1 and the Inlet Invert over a 75-minute period (Table 14). Muskeg River (MR-U) discharges were stable during this time (i.e., varied by only 0.002 m^3/s) suggesting water volumes available for diversion also remained stable; however, the inlet channel measurements indicate discharge varied by 0.424 m^3/s, and that flow in the channel increased as it traveled towards the Lake. This suggests that water from the Muskeg River may move through or beneath the inlet channel substrate as unmeasured flow contributions when the river water level elevation is greater than that of the Lake, with flows surfacing within the channel downstream of IC-1 and/or directly in the Lake.

Table 14 Discharge measurements taken at three locations along the inlet channel to Mrs. T's Lake, April 27, 2018.

Measurement location	Time of measurement	Discharge (m^3/s)
Inlet Invert (upstream)	12:45	0.571
Mid-channel	12:15	0.779
IC-1 (downstream)	11:30	0.995

A remote camera positioned at IC-1 collects photos of the inlet channel at noon each day. Figure 12 shows inlet channel conditions before open-water flow began, at the beginning of open-water flow, during the freshet flood, and during the summer low flow period of the 2018 WY. Daily discharge data for the inlet channel are provided in Appendix A1, and daily diversion volumes are provided in Appendix A3.

Figure 12 Inlet channel flow conditions during the 2018 Water Year.



Note: Although April 16 mean discharge was higher than that of August 15, the August 15 water level appears higher as viewed above. This is due to the onset of backwater conditions in the inlet channel, following filling of the Lake in May.

Continuous flows in the inlet channel that were present from March to the end of the 2018 WY can be attributed to the March 2018 excavation repairs to the channel, which were undertaken to more effectively facilitate Lake filling than occurred in previous years. The Inlet Invert was excavated from its previous elevation of approximately 278.4 m to approximately 277.45 m (Four Directions Resources 2018). 2018 flows in the inlet channel were first observed on March 20, which continued until the Lake reached FSL on May 4, 2018. Flow volumes from Muskeg River to the Lake (via the inlet channel) totaled 2,916,346 m^3 over the 2018 WY. In comparison, the estimated diversion volume reported for the 2017 WY was 17,563 m^3

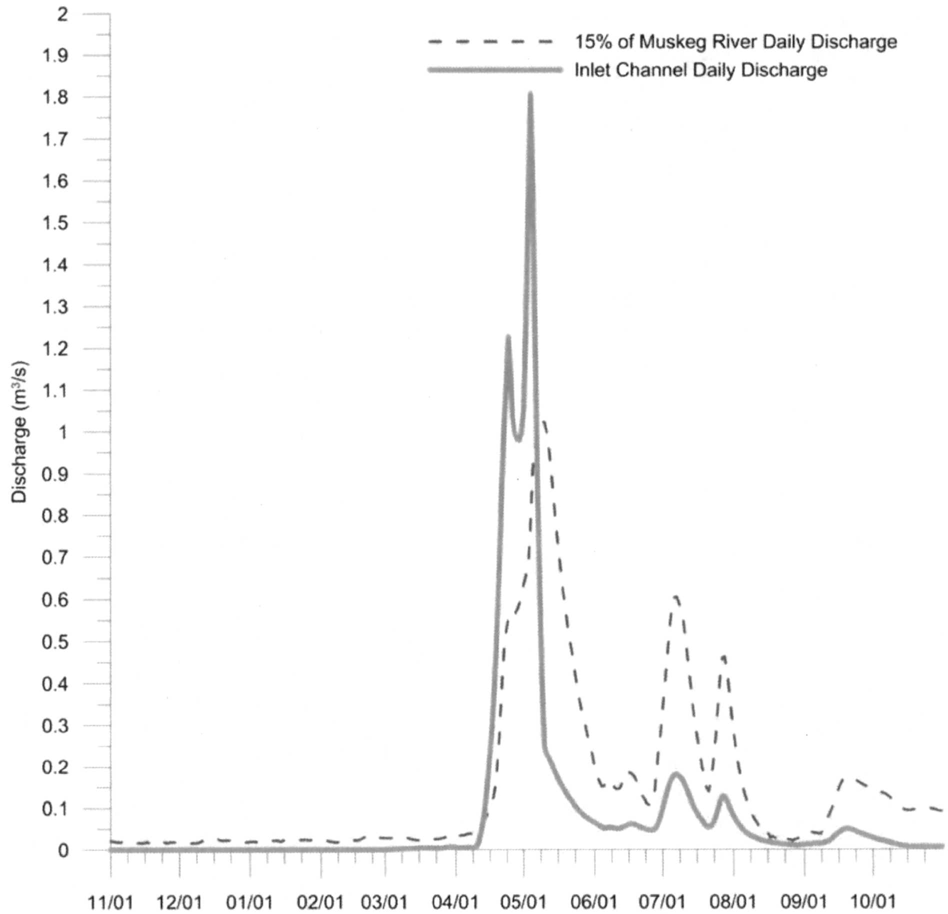
(Hatfield 2018). Upon reaching FSL, the diversion license issued to Canadian Natural for Lake filling (TDL# 00410160) was considered to be closed. Inlet channel flow volumes occurring after May 4, 2018 were not subject to the conditions of the TDL; reportable diversions (i.e., diversion volumes that occurred before May 5, 2018) totaled 1,609,805 m^3. The maximum diversion rate that occurred during the reportable period was 1.87 m^3/s, occurring on May 4, 2018. Diversion volumes and rates during the licensed period fell within the conditions of the TDL (i.e., allowance to divert up to 1,790,259 m^3 at a maximum rate of 2.36 m^3/s).

3.3.1.3 Lake Effects on Muskeg River

An estimated 2,916,346 m^3 was diverted from Muskeg River to the Lake via the inlet channel in 2018, with 1,121,040 m^3 occurring under TDL # 00394627 (from May 1, 2017 to April 30, 2018) and 488,765 m^3 occurring under TDL # 00410160 (May 1 to 4, 2018). Diversions occurred when Muskeg River discharge at MR-U exceeded approximately 0.18 m^3/s, occurring over a total of 226 complete or partial days (where diversions did not occur for the entire 24-hours) in 2018.

The NNLP states that diversions from Muskeg River to the Lake should not exceed 15% of the Muskeg River discharge; however, diversions exceeded the 15% threshold on 24 days during the 2018 WY (consecutively from April 13 to May 6), with the highest proportional diversion of 42% occurring on April 18, 2018 (Figure 13). As of May 4, 2018 (date of Lake filling and closure of the 2018 TDL), total Muskeg River water diversions had not exceeded the TDL allowances for total volume (1,790,259 m^3) or the maximum rate of diversion (i.e. a maximum instantaneous discharge of 2.36 m^3/s). Inlet channel diversions may have had a temporary ecological effect on the Muskeg River from April 13 to 20, 2018, when mean daily flows (as observed at MR-U) were already below the historical daily low flow (Q_{95}) guideline values defined in Alberta Environment (2008); Muskeg River flows during this period were as low as 0.42 m^3/s (April 13, 2018). Discussions between Canadian Natural and AER in November 2017 identified a diversion threshold to minimize impacts to the Muskeg River, where no diversions to the inlet channel were to occur at Muskeg River water level elevation of 277.4 masl (which equates to river flows below 0.51 m^3/s). However, issues with the stability of the Inlet Invert resulted in diversions occurring from March 20 to April 14, 2018, when Muskeg River flows were below 0.51 m^3/s. It should be noted that daily diversions at this time only accounted for approximately 3% of Muskeg River flows. From April 15 onwards, Muskeg River flows were above the 0.51 m^3/s diversion threshold.

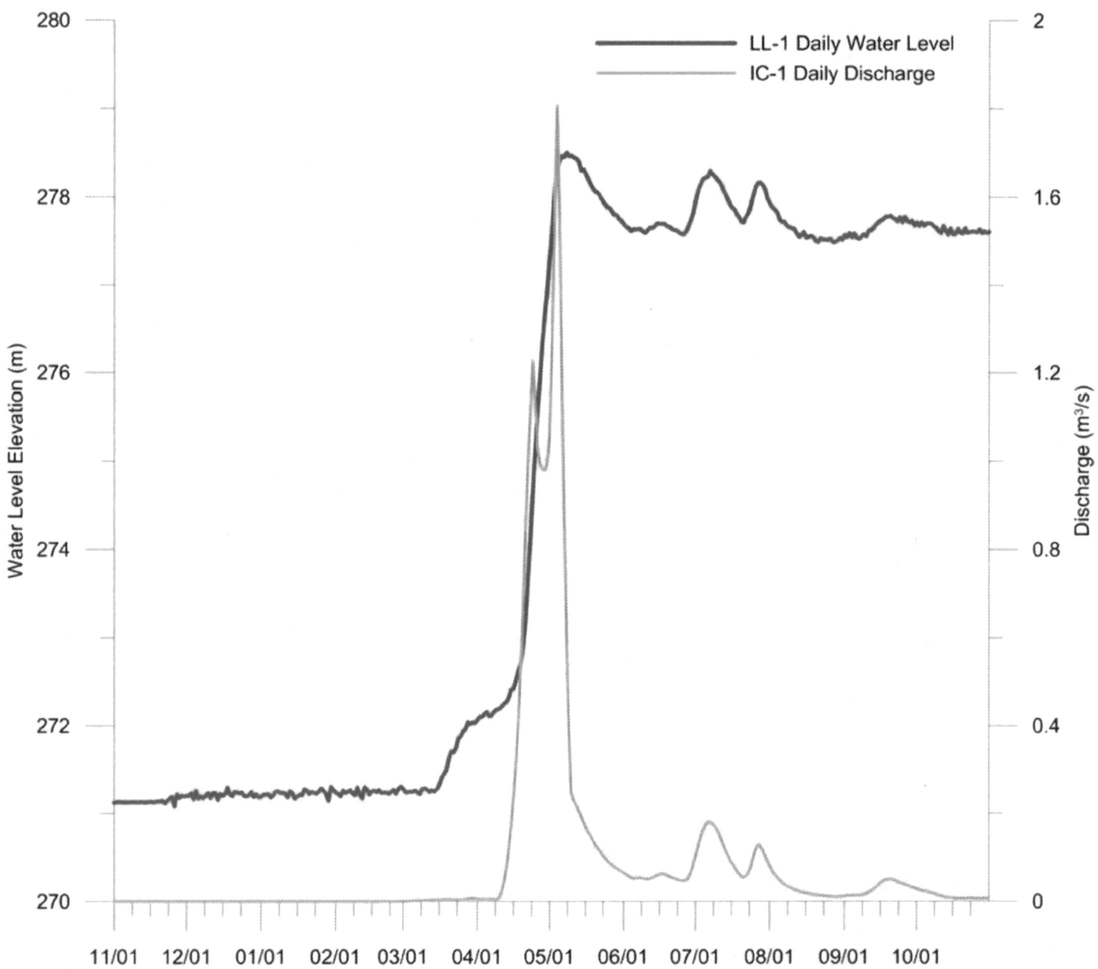
Figure 13 Inlet channel daily discharge and Muskeg River daily diversion threshold, 2018 Water Year.



3.3.1.4 Lake Levels

Water levels in the Lake were continuously monitored for the duration of the 2018 WY. The complete set of daily Lake level data is presented in Appendix A2. The Lake reached its FSL of 12.2 m (corresponding water surface elevation of 278.2 m) on May 4, 2018. Following filling (May 5 to Oct. 31, 2018), the mean Lake level was 277.79 m. The Lake was also above full operating level (i.e., the level of the Outlet sill; surface water elevation of 277.89 m) for 51 days during the 2018 WY. Lake level increased in response to inlet channel contributions that were diverted from the Muskeg River following freshet-driven flow increases in late April (Figure 14). Following freshet in April and May, Lake levels remained relatively stable for the remainder of the 2018 WY, with levels slightly below the FSL. The minimum Lake water level in 2018 was observed on April 1 (272.06 m), prior to freshet floods and Lake filling, while the maximum occurred on May 8 (278.50 m), near the peak of freshet floods and shortly after Lake filling was considered complete; this represented an annual Lake depth range of 6.439 m. The Lake level at the end of the 2018 WY measured 277.61, representing a 5.55 m increase from the start of the 2018 open-water season. Changes to Lake volumes and an assessment of the Lake's water balance are discussed in Sections 3.3.1.5 and 3.3.1.6, respectively.

Figure 14 Daily water levels recorded at Mrs. T's Lake (station LL-1) over the 2018 WY.



3.3.1.5 Lake Volume

Volumes were calculated for the Lake at FSL (12.2 m depth), the full operating level that will initiate spilling to the outlet (11.9 m depth), and for each day during the 2018 WY. The Lake depth and volume may actually differ at FSL, due to differences between the Lake design bathymetry, and the current bathymetry of the Lake. Updated bathymetry data will be used to verify Lake volumes and depths in future years. Daily Lake volumes are presented in Appendix A2. The Lake volume at FSL was estimated to be 2,306,020 m^3, while the volume at full operating level was estimated at 2,254,807 m^3. The estimated Lake volume at the conclusion of 2018 monitoring (October 31, 2018) was 2,064,838 m^3, representing an increase of 1,507,412 m^3 over the course the 2018 WY. The Lake reached FSL on approximately May 4, 2018, a maximum volume of 2,512,557 m^3 (106% full, relative to FSL) on May 8, 2018, and had a year-end volume of 2,064,838 m^3 (i.e., 90% full, relative to FSL).

3.3.1.6 Lake Water Balance

A daily volumetric water balance was calculated for the Lake using the data sources and methods described in Section 2.3.1.4; the monthly component totals for the water balance are presented in Table 15. These results demonstrate that the 2018 water balance was dominated primarily by surface water inputs (stream inflow from the inlet channel), and secondarily by unmeasured outflows (negative residual, assumed to be groundwater and subsurface flows), which respectively contributed 192% and -76% to the overall Lake storage change. The inlet channel inputs largely influenced the positive change in the Lake storage volume total for the 2018 WY, with precipitation inputs and evaporation outputs accounting for small proportions of the volumetric storage changes (i.e., 8.4% and -15%, respectively). Surface water outputs (outlet channel flows) accounted for a small proportion of volumetric losses from the Lake during the 2018 WY (-9.4% relative to the Lake storage volume).

Table 15 Monthly water balance component totals for Mrs. T's Lake, 2018 Water Year.

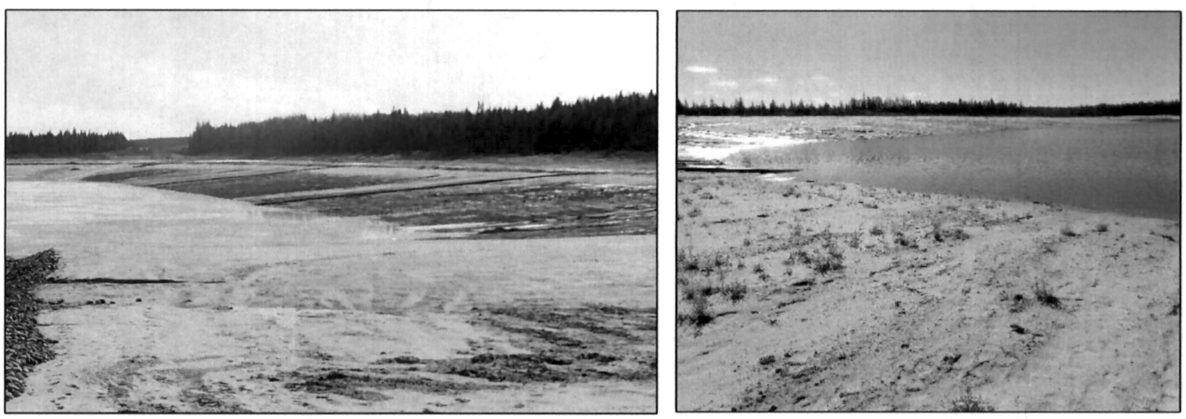
Month	Lake Storage Change (m^3/month)	Groundwater Residual (m^3/month)	Precipitation at C1 (m^3/month)	Evaporation Morton (m^3/month)	Inflow from the inlet (m^3/month)	Outflow to the outlet (m^3/month)
November	10,735	10,735	0	0	0	0
December	-1,385	-1,385	0	0	0	0
January	12,656	12,656	0	0	0	0
February	5,569	5,569	0	0	0	0
March	116,862	113,087	0	1,495	5,270	0
April	1,078,605	-24,655	1,841	14,351	1,115,770	0
May	350,721	-648,394	3,848	43,693	1,162,166	123,206
June	42,279	-88,955	40,776	52,535	142,992	0
July	71,207	-213,710	51,087	55,610	308,794	19,354
August	-209,007	-255,982	16,914	41,045	71,107	0
September	70,753	-4,273	13,497	16,145	77,674	0
October	-32,727	-62,524	0	2,776	32,573	0
2018 WY total	1,516,265	-1,157,833	127,962	227,650	2,916,346	142,560

The negative residual volumes of groundwater flows described in Table 15 suggest that despite the Lake filling and maintaining a positive storage change (i.e., the volume of the Lake increased overall during the 2018 WY), a portion of the Lake water balance is being lost either as recharge to an unconfined shallow groundwater aquifer (aquifer described in Norwest 2013) or to subsurface flows. Groundwater flow in the vicinity of the Lake was not directly monitored during the 2018 open-water season; however, field crews observed seepage water daylighting from rills on the southern Lake shore during periods of zero rainfall in 2017 (Figure 15), suggesting that shallow groundwater movement above the elevation of the lean oil sands (LOS) liner of the Lake is possible. Additionally, evidence of flow beneath the inlet channel (Table 14) and observations of flow occurring within the inlet and outlet channel substrates in past years suggest that unmeasured volumes may be flowing beneath the outlet channel to Muskeg River. Lake levels were above the outlet sill elevation for 51 days during the 2018 WY while outlet flows were only measured over 37 days, providing further evidence that flow may be travelling through or below the outlet channel substrate. The

total unmeasured residual volume is not necessarily limited to groundwater and subsurface flows. It is possible that differences between the actual Lake volume and the design volume will account for a portion of the unmeasured volume of the water balance; as stated in Sections 2.3.1.3 and 3.3.1.5, updated bathymetry data will be used to verify Lake volumes in future years. Similarly, the inlet channel flows likely reversed at times when the Lake or inlet channel level was higher than the Muskeg River (at MR-U) water level, which would also account for a portion of the unmeasured Lake output volume. Inlet channel flow was observed to be stagnant or reversed on July 22, August 20-22, and October 4, 2018 (D. Chudobiak personal communication).

The data collected in support of the 2018 monitoring program confirm the Lake volume increased over the 2018 WY. These positive changes in Lake volume storage were predominantly influenced by surface water inputs from the inlet channel, which appear to have outweighed the unmeasured residual flow losses. It is unclear whether the Lake is holding water as designed, as the pathways of this negative residual volume are currently unknown. Further investigation in future years will be required to ascertain whether additional sources of water output are substantially contributing to the water balance of the Lake.

Figure 15 Rill erosion from ponding water and suspected shallow groundwater seepage on the south shore of the Lake, April 12, 2017.

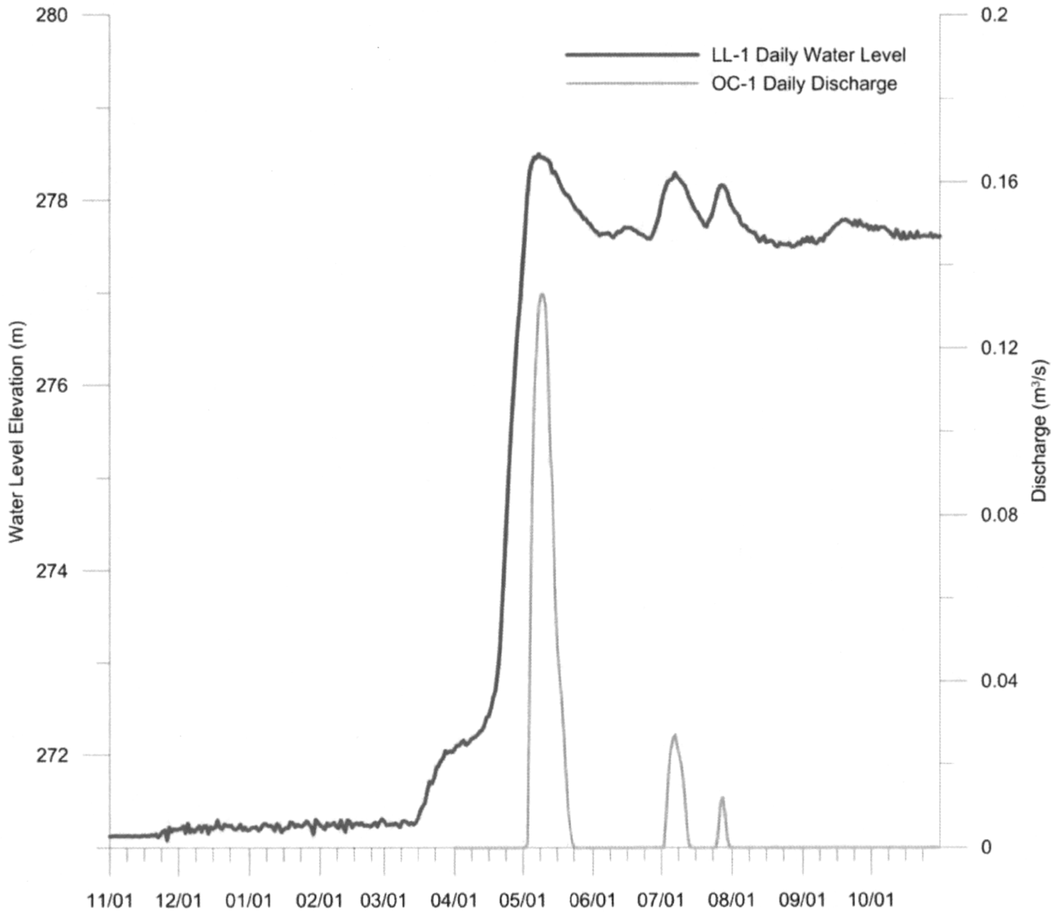


3.3.1.7 Outlet Channel

Monitoring of continuous water levels and discharges were completed in the outlet channel (OC-1 hydrometric station) during the 2018 WY. The Lake began spilling to the outlet channel on May 3, after reaching the outlet sill elevation on approximately May 3; 2018 represents the first year on record that the outlet channel conveyed surface flow from the Lake to Muskeg River. The outlet channel contained flow for a total of 37 days during the 2018 WY, including May 3 to 23, July 2 to 14, and July 26 to 30. A maximum instantaneous discharge of 0.142 m^3/s occurred on May 11, 2018. Daily discharge data for the OC-1 hydrometric station demonstrates the relationship between Lake levels and outlet channel flow responses (Figure 16). Water level data indicate the Lake was above the outlet sill elevation for 51 days in 2018, suggesting that the channel should have conveyed surface flow on 51 days; however, water level data collected at the OC-1 station registered flow on only 37 of these days. All fourteen days with Lake levels above the outlet sill but with no flow recorded at OC-1 occurred on the days leading up to and following the

outlet channel flow periods listed above. This suggests that when Lake levels are just above the outlet sill, some water may infiltrate the cobble and gravel substrate of the outlet channel and travel towards Muskeg River in the form of subsurface flow.

Figure 16 Daily outlet channel discharge and Lake levels, 2018 Water Year.



The lower Muskeg River station (MR-D) was installed to assess whether Muskeg River flows have any backwatering effect on the outlet channel. Backwater effects may cause the outlet channel to reverse flow towards the Lake, complicating inflow and outflow volume calculations. Conditions that would cause backwatering to occur were not observed in 2018, as the outlet channel water levels (at OC-1) always exceeded those of the Muskeg River (at MR-D) during the 2018 WY. These results confirm that the Muskeg River had no backwater effect on the outlet channel in 2018.

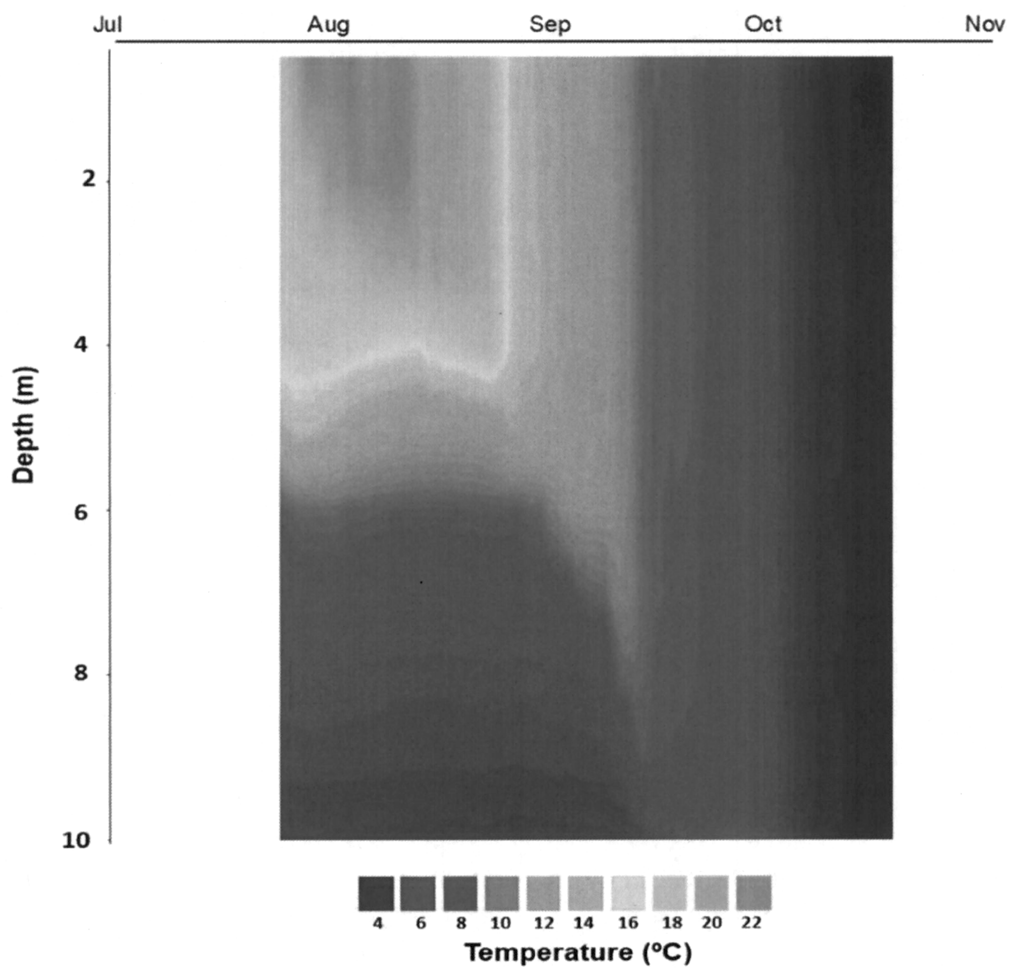
3.3.2 Water Quality

Analytical water quality samples and supporting in situ measurements were collected from the middle of the Lake (PZ-1) and near the Lake outlet in July and September 2018. Limnological depth profiles were collected in July, August, and September and near-continuous water quality data were measured with three datasondes and a thermostring deployed at the PZ-1 sampling station. Water quality samples were analyzed for the full suite of analytes listed in Table 10. Sampling results are discussed in the following sections.

3.3.2.1 Limnological Water Quality

Water temperature thermistors deployed at one-metre depth intervals through the water column were operational at the mid-lake station (PZ-1) from late July to mid-October 2018 (Figure 17). The Lake thermally stratified prior to the July deployment of temperature loggers, with a prominent thermocline already formed at 4 m below the surface (Figure 17). Thermal stratification started to degrade in late August, with complete turnover occurring in mid-September.

Figure 17 Daily average water temperature in the Mrs. T's Lake, collected at one-metre intervals from the lake surface to bottom, July 24 to October 18, 2018.



Discrete temperature and DO profiles collected from the mid-lake station (PZ-1) are presented in Figure 18. The temperature profiles showed good agreement with thermistor measurements, with a 4 m depth thermocline present in July and persisting into August. Relatively homogenous temperatures were observed from the water surface to a depth of 9 meters on September 13, suggesting lake turnover had occurred. DO levels in the Lake showed a strong correlation to temperature in 2018, with DO concentrations stable at approximately 9 mg/L above the thermocline and dropping to levels of less than 1 mg/L below it (Figure 18).

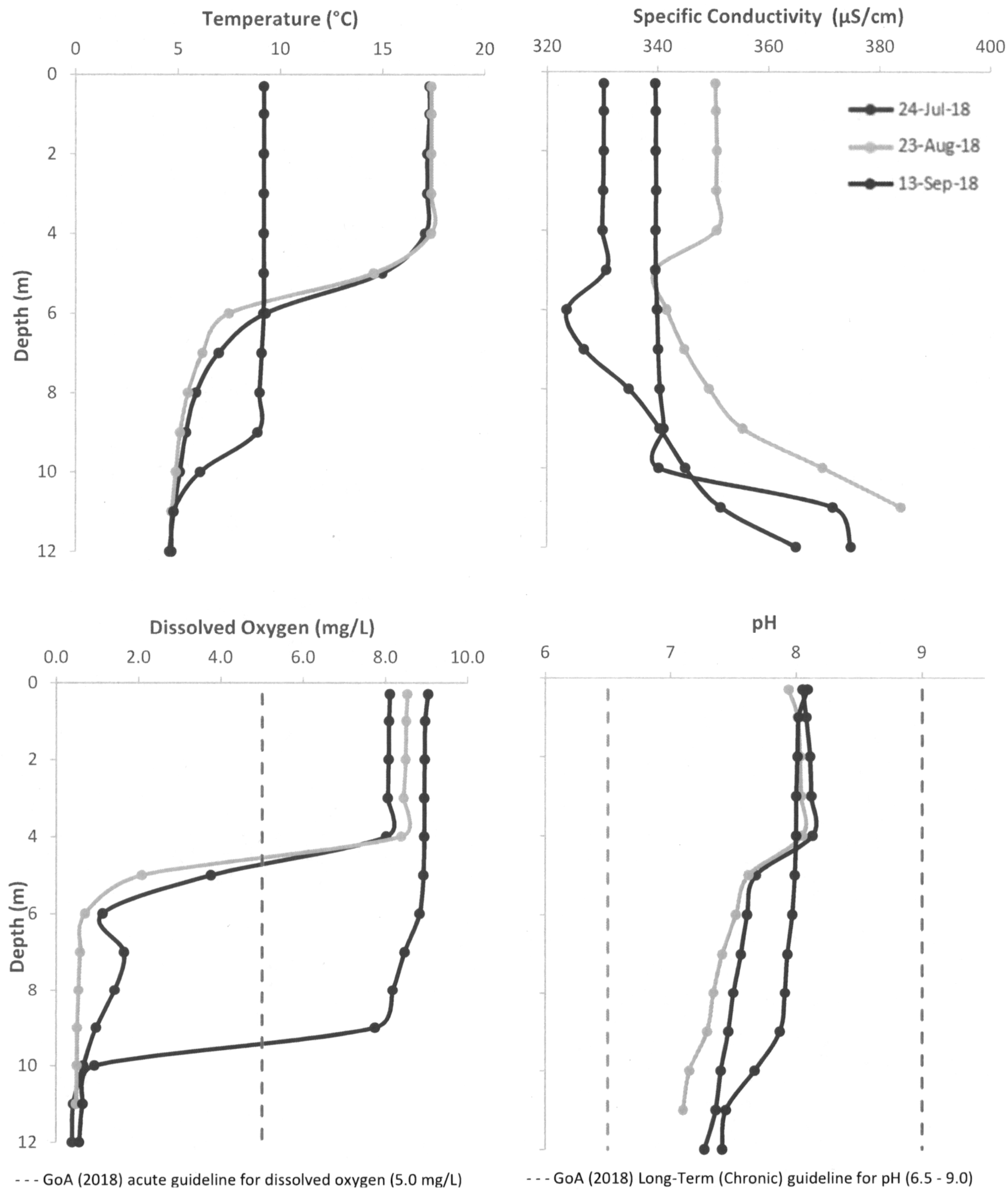
Dissolved oxygen levels of 5.5 mg/L are considered by the Canadian Council of Ministers of the Environment (CCME) to be the lowest acceptable concentration to support all life-stages of all species of fish (CCME 1999, GoA 2018), although many species in northeastern Alberta are known to tolerate concentrations as low as 1 mg/L (Hatfield 2013b). According to published habitat suitability models (Inskip 1982; Casselman and Lewis 1996), northern pike (*Esox lucius*) are capable of surviving several days at DO levels as low as 0.1 mg/L, for prolonged periods at DO levels as low as 1 mg/L during winter months, and in concentrations as low as 2 mg/L in summer months (at maximum water temperatures of 28°C); these tolerances are also suggested to be inversely related to size (Inskip 1982). Similarly, the published habitat suitability model for white sucker (*Catostomus commersonii*) (Twomey 1984) indicates adult and juvenile white sucker have a high tolerance to hypoxic conditions, with sub-lethal effects on fry only observed at DO levels below 2.5 mg/L (Siefert and Spoor 1974). Juvenile white sucker have been observed to tolerate dissolved oxygen concentrations down to 0.98 mg/L at 26 °C (Smale and Rabeni 1995), indicating this species is also capable of surviving periods of low DO, particularly during the colder winter months. The regional habitat suitability models for the oil sands region (Golder 2008) consider late winter DO above 1 mg/L to provide excellent conditions for pearl dace and above average conditions for lake chub.

DO concentrations below the CCME guideline of 5.5 mg/L were observed at the pelagic station at depths greater than 4 m in July and August, and greater than 9 m in September (Figure 18), and all but one of these observations were also below the 2.0 mg/L summer minimum DO guideline referenced in Inskip (1982); however, it should be noted that the corresponding water temperatures at these depths were well below the 28°C water temperature associated with the Inskip guideline. Fish are not expected to be adversely affected by periodic and localized anoxia, as this area in the Lake will simply be avoided until re-oxygenation occurs during spring or fall turnover.

pH profiles showed a moderate correlation to water temperature in 2018, with higher (more alkaline) values observed above the thermocline in July and August (Figure 18). The September pH profile was collected after lake turnover, as evidenced by the relatively homogenous pH that extended to a depth of 9 m. All pH values remained alkaline in 2018 (pH>7.0), and there were no observed exceedances of the CCME guidelines for the protection of aquatic life (6.5 to 9.0; CCME 2011).

Specific conductance remained stable with depth until reaching the thermocline, then generally demonstrated an increasing trend until reaching the lake bottom (Figure 18). This correlation with water temperature was present in all three of the 2018 open-water profiles, although the increase in specific conductivity appeared to occur just above the temperature inflection depth in September.

Figure 18 Seasonal depth profiles of temperature, pH, dissolved oxygen, and specific conductance in Mrs. T's Lake, 2018.



3.3.2.2 Continuous Water Quality

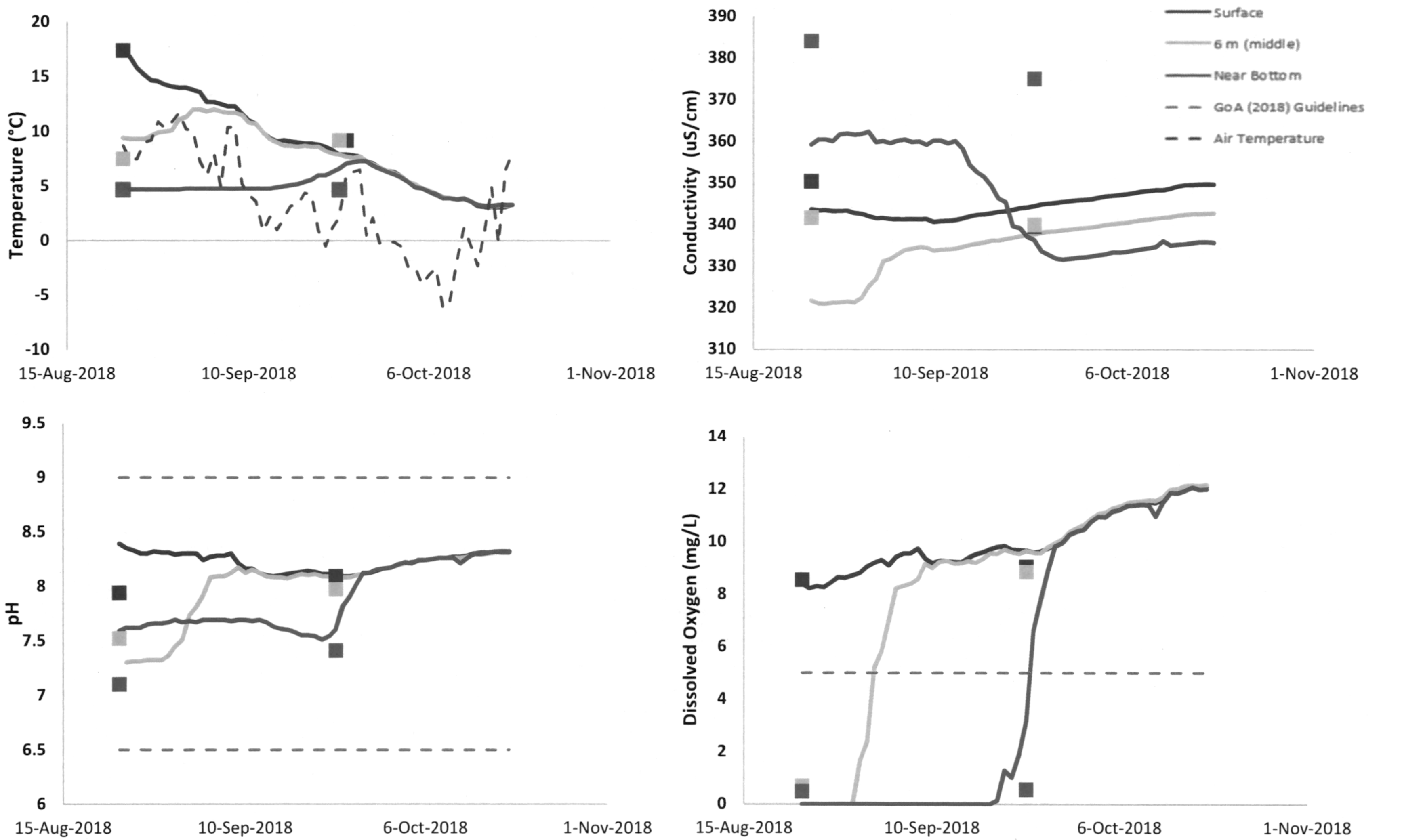
Near-continuous measurements of water temperature, DO, pH, and specific conductance were collected from data sondes deployed at near-surface, 6 m, and 12 m depths at the mid-lake station (PZ-1). Summary statistics are presented in Table 16 and Figure 19, and the raw dataset is provided in Appendix A3.

From August to October 2018, water temperature patterns at the near-surface station correlated with ambient air temperatures, decreasing from early August to October. Water temperature at the 6 m and near-bottom locations were lower than surface water temperatures until late August and early September respectively, as seasonal mixing occurred through the water column. pH at the surface remained relatively stable from August to October. Following the same pattern as temperature, pH levels at the 6 m and near bottom locations were lower than surface values until late August and early September respectively, when turnover resulted in homogenous pH through the water column. DO concentrations at the surface increased gradually from August to October, while DO at the 6 m and near bottom locations remained below 1.0 mg/L until fall turnover occurred. Specific conductance remained relatively stable from August to October for all three depth locations, with the exception of a decrease that occurred between from mid to late September at the near-bottom location in conjunction with fall turnover. All in situ parameters remained within the guidelines for the protection of freshwater aquatic life (GoA 2018), with the exception of DO at the 6 m and 12 m locations during summer months. Continuous water quality data correlated well with limnological depth profile data, although specific conductance measurements taken with the handheld meter were generally higher than those reported by the datasonde (Figure 19).

Table 16 Summary statistics for near-continuous measurements of water quality at PZ-1 August to October 2018.

	Min	Mean	Max	Number of Observations
Surface				
Temperature (°C)	2.7	8.8	17.6	5,376
Specific Conductivity (µS/cm)	340	345	351	5,374
pH	8.06	8.22	8.40	5,365
ODO (%)	77.9	85.4	93.3	5,376
Conductivity (µS/cm)	200	238	295	5,374
DO (mg/L)	8.01	9.99	12.2	5,376
Middle (6 m)				
Temperature (°C)	3.0	7.8	13.5	5,378
Specific Conductivity (µS/cm)	320	335	343	5,378
pH	7.29	8.02	8.33	5,326
ODO (%)	-2.4	68.9	93.0	5,378
Conductivity (µS/cm)	199	225	261	5,375
DO (mg/L)	-0.27	8.36	12.3	5,378
Bottom (11 m)				
Temperature (°C)	3.1	5.0	7.7	5,377
Specific Conductivity (µS/cm)	331	346	365	5,374
pH	7.44	7.88	8.34	5,365
ODO (%)	-2.5	37.1	92.7	5,346
Conductivity (µS/cm)	195	214	223	5,375
DO (mg/L)	-0.32	4.73	12.3	5,375

Figure 19 Daily average water quality records and air temperature collected from PZ-1 surface, 6 m and 12 m depths, and the corresponding in situ profile measurements Mrs. T's Lake, 2018.



3.3.2.3 Analytical Water Chemistry

The analytical water chemistry component of the Program measures a wide range of conventional variables, nutrients, major ions, and metals that are important indicators of an aquatic system's ability to support biological colonization. Key water quality endpoints measured mid-lake and at the outlet of Mrs. T's Lake are summarized in Table 17. Surface and near-bottom samples were collected at the mid-lake station (PZ-1) in the summer and fall of 2018 while surface samples were collected from near the outlet during both sampling events. The lab reports for the 2018 sampling programs are provided in Appendix A3.

The pH of water affects transformation processes among various forms of nutrients (e.g., nitrogen, phosphorus) and metals, which influences toxicity in the water column and the bioavailability of dissolved forms of nutrients. Direct effects of pH on organisms become more severe as pH shifts away from the natural range (6.5 to 9.0). In 2018, all laboratory-derived pH values measured in both basins were within the GoA (2018) guideline range (Table 17), with good agreement observed between lab and in situ measurements.

Total suspended solids (TSS) consist of materials such as clay, sand, silt, organic and inorganic matter, and plankton and other microorganisms. Concentrations of TSS in the Lake were above the analytical detection limit (3 mg/L) in all but one surface sample in 2018 (Table 17). The CCME guideline for TSS (CCME 2011) is dependent on baseline concentrations; for clear flow systems like the Lake, TSS levels should not increase by more than 10 mg/L above background levels for any short-term exposure (i.e., 24-hour period). TSS concentrations in the Lake ranged from <3.0 mg/L (buoy bottom – fall) to 8.7 mg/L (lake outlet – fall) in 2018 (Table 17).

Total dissolved solids (TDS) is a measure of the concentration of dissolved matter in water, primarily carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, and major cations (Ca, Mg, Na, K). TDS concentrations are of interest because dissolved species affect metal concentrations by forming salts, thereby removing potentially toxic dissolved metals from solution. TDS levels measured in the Lake in 2018 were moderate, ranging from 172 mg/L to 244 mg/L.

Total ammonia concentrations in the near-bottom samples from the Lake were higher than the near-surface samples for both sampling events (Table 17); ammonification of organic matter and nitrite, particularly under suboxic conditions, is a commonly observed process that results in elevated ammonia concentrations in the deep waters of lakes. Low dissolved oxygen concentrations at the PZ-1 near-bottom location indicate the suboxic conditions required for ammonification are present in Mrs. T's Lake (Figure 19).

Alberta Environment (AENV 2008) established Muskeg River watershed-specific guidelines for acute (0.20 mg/L) and chronic (0.055 mg/L) exposure to boron, which is less than five percent the level recommended in CCME guidelines for the protection of aquatic life (1.2 mg/L; CCME 2011). All 2018 summer and fall samples from the Lake exceeded the Muskeg River water quality guidelines (Table 17), although none were above the CCME guideline. Water quality data suggest that boron concentrations in Mrs. T's Lake are being influenced by the Muskeg River basin, where historical concentrations have regularly exceeded the Muskeg River chronic exposure guidelines (Hatfield 2015, RAMP 2016).

Dissolved aluminum naturally occurs in surfaces water in low concentrations, but at elevated concentrations it can accumulate on the gills of fish, affecting respiration; dissolved aluminum in the Lake remained well below the GoA (2018) guideline of 0.05 mg/L in all 2018 samples.

Total iron exceeded the GoA (2018) guidelines for the protection of aquatic life in summer and fall samples from the near-bottom stratum of the mid-lake station (PZ-1), and in the near-surface sample taken near the Lake outlet in fall (Table 17). Dissolved iron exceedances were limited to the near-bottom sample from the pelagic station in fall. Concentrations of total and dissolved iron in the Muskeg River basin have regularly exceeded GoA (2018) guidelines (Hatfield 2016a, JOSMP 2016), indicating that the concentrations observed in Mrs. T's Lake in 2018 were influenced by and representative of the Muskeg River source waters.

The Year One water quality sampling events were completed soon after Mrs. T's Lake reached FSL in May 2018. As expected, the water quality characteristics of the Lake were generally representative of the Muskeg River, with only iron and boron exceeding guidelines for the protection of aquatic life. It is expected that future years of monitoring will show the water quality in the Lake slowly shifting towards the typical characteristics of a lentic system.

Table 17 Seasonal concentrations of select water quality endpoints measured in Mrs. T's Lake, 2018.

Analyte	Units	Guideline	Summer			Fall		
			Buoy (PZ-1)		Lake Outlet	Buoy (PZ-1)		Lake Outlet
			Bottom	Top		Bottom	Top	
Physical variables								
Alkalinity, Total (as $CaCO_3$)	mg/L	-	158	156	154	163	161	154
Conductivity	µS/cm	-	335	325	319	331	318	316
Hardness (as $CaCO_3$)	mg/L	-	155	152	149	181	175	176
pH	pH units	6.5-9.0	8.00	8.21	8.22	7.90	8.13	8.14
Total Dissolved Solids	mg/L	-	244	234	230	222	216	172
Total Suspended Solids	mg/L	-	4.5	4.6	6.0	6.7	<3.0	8.7
Nutrients								
Total Ammonia	mg/L	-	0.183	<0.050	<0.050	0.415	<0.050	<0.050
Chlorophyll-a	µg/L	-	0.34	1.61	1.88	1.15	3.71	3.83
Dissolved Organic Carbon	mg/L	-	15.8	16.6	17.2	18.0	17.1	17.3
Nitrate and Nitrite	mg/L	-	0.167	0.052	<0.022	<0.022	<0.022	<0.022
Total Phosphorus	mg/L	-	0.0296	0.0128	0.0139	0.0576	0.0137	0.0154
Dissolved Phosphorus	mg/L	-	0.0083	0.0143	0.0062	0.0533	0.0087	0.0106
Total Nitrogen[1]	mg/L	-	0.3671	0.252	0.222	0.972	0.552	0.622
Major Ions[2]								
Bicarbonate	mg/L	-	193	190	188	199	197	188
Dissolved Calcium	mg/L	-	42.2	41.4	40.2	51.2	49.2	49.5
Chloride (Cl)	mg/L	120	5.50	7.98	4.36	5.14	4.36	4.34
Dissolved Magnesium	mg/L	-	12	11.9	11.8	12.8	12.7	12.7
Dissolved Potassium	mg/L	-	2.08	1.92	1.89	2.24	2.09	2.12
Dissolved Sodium	mg/L	-	13.7	12.3	12.4	14.2	13.3	13.3
Sulphate	mg/L	309-429[3,4]	20.5	31.4	19.3	17.4	18.7	18.7
Organic compounds								
Hydrocarbons, Recoverable (I.R.)	mg/L	-	<1	<1	<1	<1	<1	<1
Phenols (4AAP)	mg/L	0.004	0.0016	0.0018	0.0017	0.0040	0.0014	0.0018
Naphthenic Acids	mg/L	-	0.37	0.29	0.33	0.76	<0.10	<0.10

Table 17 (Cont'd.)

Analyte	Units	Guideline	Summer			Fall		
			Buoy (PZ-1)		Lake Outlet	Buoy (PZ-1)		Lake Outlet
			Bottom	Top		Bottom	Top	
Dissolved Metals								
Dissolved Aluminum	mg/L	0.05	<0.005	<0.005	<0.005	0.003	<0.001	0.0012
Total Metals								
Total Aluminum	mg/L	0.1	0.024	0.037	0.083	0.075	0.016	0.070
Total Arsenic	mg/L	0.005	<0.00050	<0.00050	0.00050	0.00086	0.00035	0.00037
Total Boron	mg/L	0.055[5]	**0.081**	**0.071**	**0.071**	**0.083**	**0.075**	**0.075**
Total Mercury	µg/L	0.005,0.013[6]	0.00088	0.00097	0.00101	0.00140	0.00067	0.00098
Total Molybdenum	mg/L	0.0028[5]	0.00044	<0.00025	0.00028	0.00060	0.00036	0.00034
Other variables that exceeded guidelines								
Iron (Fe)-Dissolved	mg/L	0.3	0.127	<0.050	<0.050	**3.540**	0.052	0.046
Iron (Fe)-Total	mg/L	0.3	**0.418**	0.152	0.268	**4.560**	0.188	**0.310**
Chlorine, Total	mg/L	0.0005	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**

Guidelines are GoA 2018 unless otherwise noted.

Values shaded and in **bold** indicate concentrations exceeding guidelines for the protection of aquatic life.[1] Total nitrogen = Nitrate+nitrite plus total Kjeldahl nitrogen (TKN); Nondetectable results were assumed to be equal to the detection limit for calculating total nitrogen.

[2] Concentrations of major ions were determined by the laboratory method ICPMS in summer and ICPOES in fall.[3] Hardness dependent guideline.

[4] BC MOE (2015) guideline.

[5] Muskeg River Watershed Mean Water Quality Management guidelines (AENV 2008).

[6] Guidelines for chronic and acute total mercury concentrations, respectively (GoA 2018).

Figure 20 and Figure 21 present piper plots of the ionic composition of Mrs. T's lake in the summer and fall of 2018, respectively. The Lake was bicarbonate-dominated, indicating ionic composition that is strongly influenced by surface water inputs. Overall, the ionic composition of the Lake in 2018 was comparable to the Muskeg River watershed (Hatfield 2015).

Figure 20 Piper diagram of ion concentrations in the main basin of the Mrs. T's Lake, summer 2018.

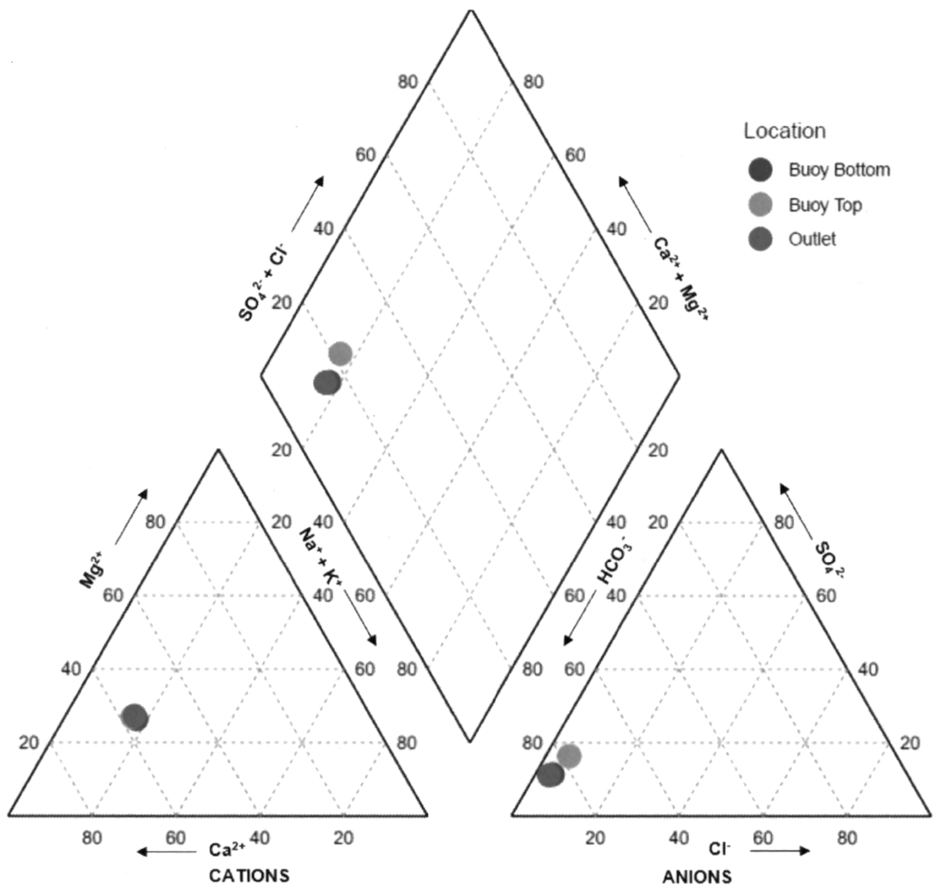
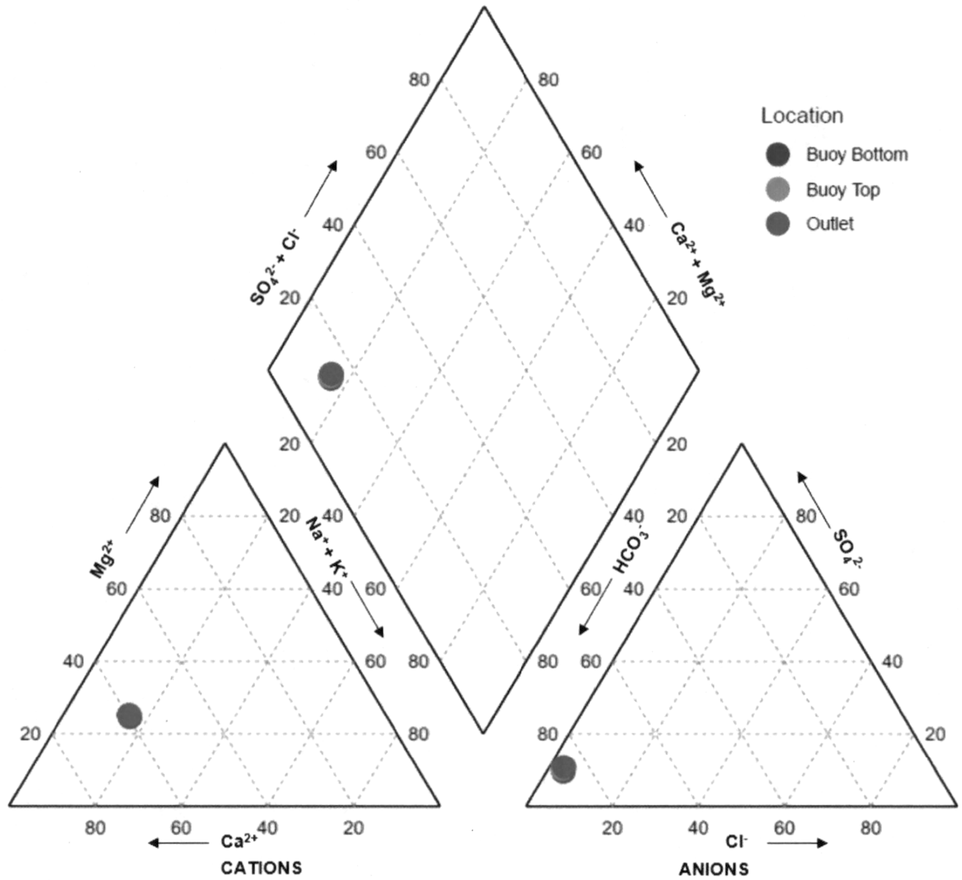


Figure 21 Piper diagram of ion concentrations in the main basin of the Mrs. T's Lake, fall 2018.



3.3.2.4 Trophic Status

In 2018, total phosphorus concentrations in Mrs. T's Lake ranged from 0.0128 mg/L (PZ-1 surface in fall) to 0.0533 mg/L (PZ-1 near-bottom in fall). Based on these numbers, the trophic status index (TSI) was determined to range from 40.9 to 62.6, suggesting a mesotrophic to slightly eutrophic system (Table 18) (Wetzel 2001).

TN:TP molar ratios in surface waters ranged from 35.3 to 156.9, while ratios varied from 21.2 to 27.4 in near-bottom samples. The TN:TP molar ratio was greater than 50 in surface water samples collected from the mid-lake station and near the outlet in fall, while all other samples measured between 20 and 50 (Table 18). Overall, these results suggest that Mrs. T's Lake is likely a phosphorus-limited system; however, it should be noted that transient limitation of algal growth by nitrogen is often observed in P-limited northern freshwater systems during the growing season, and that this phenomenon may occur in Mrs. T's Lake.

Table 18 Seasonal trophic status, trophic class, total nitrogen to phosphorus molar ratios, and the predicted limiting nutrient in Mrs. T's lake, 2018.

Season	Station	Sample	Trophic Status	Trophic Class	TN:TP (molar)	Limiting Nutrient
Summer	PZ1	Surface	40.9	Mesotrophic	43.6	Total N or P
Fall	PZ1	Surface	41.9	Mesotrophic	156.9	Total P
Summer	PZ1	Bottom	53.0	Eutrophic	27.4	Total N or P
Fall	PZ1	Bottom	62.6	Eutrophic	21.2	Total N or P
Summer	Outlet (IC-1)	Surface	42.1	Mesotrophic	35.3	Total N or P
Fall	Outlet (IC-1)	Surface	43.6	Mesotrophic	89.3	Total P

3.3.3 Sediment Quality

The sediment monitoring component of the Program is designed to assess two indicators of environmental quality: the physio-chemical characteristics of the sediments, and the potential for the sediments to cause mortality or inhibit growth in controlled laboratory assays using cultured organisms. These two indicators are discussed separately in the following sections.

3.3.3.1 Physio-Chemical Characteristics

The substrate of Mrs. T's Lake is predominantly sand, which is the result of a mineral soil liner that was installed to reduce potential surface water interactions with the natural ores (≥ 7% bitumen content) and lean oil sands (<7% bitumen content) present in the vicinity of the Lake footprint (Norwest Corporation 2013). During construction, lean oil sands were used to cap any exposures of natural ores, and then all lean oil sands were capped with a minimum 0.5 m of clean sand. Cobble armoring was placed near the Lake inlet and outlet to minimize erosion during infilling. Inlet and outlet areas were also lined with coarse gravel to provide spawning habitat for fish.

Select sediment quality endpoints measured in samples collected in August 2018 from the littoral zone that received inlet channel flows during the Lake filling process (LZ-INLET), the deep-water station (PZ-1), and a composite sample collected from eight littoral stations positioned around the perimeter of the Lake are summarized in Table 19; the complete laboratory sediment quality dataset for 2018 is provided in Appendix A4. The deep-basin sediments were comprised primarily of sand, with smaller proportions of silt and clay, and minor organic carbon fractions. The substrate compositions of the littoral zone samples were predominately comprised of sand, with smaller silt and clay proportions. The relative contributions of silt, clay, and organic carbon in the Lake are expected to increase over time, as suspended materials imported from Muskeg River and autochthonous biomass generated within the Lake continue to settle out of the water column and accumulate over the sand cap.

All metal concentrations were below applicable interim sediment quality guidelines (ISQG) and probable effects levels (PEL) at all three sampling stations in 2018. Metals readily adsorb to organic matter and clays, so the low concentrations of metals in sediment samples may be a consequence of the higher percentage of sand and lower percentage of silt and fine-clay sized particles.

Low molecular-weight compounds (Fraction 1 including BTEX, and Fraction 2) are highly volatile and have high aqueous solubilities that allow transport through the water column, making them more bioavailable (and toxic) to freshwater aquatic life (AENV 2001). In contrast, higher molecular weight hydrocarbons (Fractions 3 and 4) have much lower aqueous solubilities, resulting in compounds that are more persistent in the environment but have less potential for toxic effects. Hydrocarbon concentrations in the Lake were dominated by higher molecular weight compounds in 2018, all of which were below their respective guidelines for coarse-grained (median > 75 µm) surface soils in a residential/parkland setting (CCME 2008).

3.3.3.2 PAH Toxicity

Concentrations of all analyzed PAH compounds were below detection limits in all three sediment samples collected from Mrs. T's Lake in 2018 (Table 19); consequently, no PAH Hazard Index could be calculated.

Table 19 Sediment quality data collected from MRME Compensation Lake in August 2018.

Variable	Units	Guideline		Sampling Location		
		ISQG	PEL	LZ-INLET	LZ-COMP	PZ-1
Physical Variables						
Moisture	%	-	-	23	20.7	31.3
Total Organic Carbon	%	-	-	0.258	0.223	0.710
Sand	%	-	-	95.8	94.2	59.8
Sand (2.0 mm - 0.05 mm)	%	-	-	97.8	96.9	68.6
Silt	%	-	-	4.2	5.8	20.2
Silt (0.05 mm - 2 µm)	%	-	-	1.4	2.6	23.1
Clay	%	-	-	<1.0	<1.0	20.0
Clay (<2 µm)	%	-	-	<1.0	<1.0	8.3
Texture	-	-	-	Sand	Sand	Sandy loam/ Sandy clay
Total Petroleum Hydrocarbons						
BTEX	mg/kg	-	-	<10	<10	<10
Fraction 1 (C6-C10)	mg/kg	30[1]	-	<10	<10	<10
Fraction 2 (C10-C16)	mg/kg	150[1]	-	<20	<20	<20
Fraction 3 (C16-C34)	mg/kg	300[1]	-	47	73	23
Fraction 4 (C34-C50)	mg/kg	2800[1]	-	39	66	34
Select PAHs						
Total PAHs	mg/kg	-	-	<1.309	<1.309	<1.309
Total Parent PAHs	mg/kg	-	-	<0.219	<0.219	<0.219
Total Alkylated PAHs	mg/kg	-	-	<1.09	<1.09	<1.09
Predicted PAH Toxicity	H.I.	1	1	2	2	2

Values in ***bold italics*** indicate concentrations exceeding guidelines;

[1] Guideline is for residential/parkland course (median grain size > 75 µm) surface soils (CCME 2008).

[2] PAH toxicity not calculated; all PAH results were below detection limit.

[3] Values represent percent difference from control observations.

Table 19 (Cont'd.)

Variable	Units	Guideline		Sampling Location		
		ISQG	PEL	LZ-INLET	LZ-COMP	PZ-1
Select PAHs (Cont'd.)						
Acenaphthene	mg/kg	0.00671	0.0889	<0.005	<0.005	<0.005
Acenaphthylene	mg/kg	0.00587	0.128	<0.005	<0.005	<0.005
Anthracene	mg/kg	0.0469	0.245	<0.004	<0.004	<0.004
Benzo(a)anthracene	mg/kg	0.0317	0.385	<0.01	<0.01	<0.01
Benzo(a)pyrene	mg/kg	0.0319	0.782	<0.01	<0.01	<0.01
Chrysene	mg/kg	0.0571	0.862	<0.01	<0.01	<0.01
Dibenz(a,h)anthracene	mg/kg	0.00622	0.135	<0.005	<0.005	<0.005
Fluoranthene	mg/kg	0.111	2.355	<0.01	<0.01	<0.01
Fluorene	mg/kg	0.0212	0.144	<0.01	<0.01	<0.01
Naphthalene	mg/kg	0.0346	0.391	<0.01	<0.01	<0.01
Phenanthrene	mg/kg	0.0419	0.515	<0.01	<0.01	<0.01
Pyrene	mg/kg	0.053	0.875	<0.01	<0.01	<0.01
Total Metals						
Aluminum (Al)	mg/kg	-	-	450	394	5,460
Antimony (Sb)	mg/kg	-	-	<0.1	<0.1	<0.1
Arsenic (As)	mg/kg	5.9	17	0.35	0.36	1.77
Barium (Ba)	mg/kg	-	-	5.86	5.63	38.70
Beryllium (Be)	mg/kg	-	-	<0.1	<0.1	0.27
Bismuth (Bi)	mg/kg	-	-	<0.2	<0.2	<0.2
Boron (B)	mg/kg	-	-	<5.0	<5.0	5.9
Cadmium (Cd)	mg/kg	0.6	3.5	<0.02	<0.02	0.02
Calcium (Ca)	mg/kg	-	-	2,020	3,070	8,870
Chromium (Cr)	mg/kg	37.3	90	1.17	1.07	10.40
Cobalt (Co)	mg/kg	-	-	0.41	0.42	2.92
Copper (Cu)	mg/kg	35.7	197	0.90	0.58	4.41
Iron (Fe)	mg/kg	-	-	1,210	1,060	7,900
Lead (Pb)	mg/kg	35	91.3	0.73	0.72	4.02
Lithium (Li)	mg/kg	-	-	<2.0	<2.0	6.4
Magnesium (Mg)	mg/kg	-	-	680	960	2,490
Manganese (Mn)	mg/kg	-	-	26.0	36.6	102.0
Mercury (Hg)	mg/kg	0.17	0.486	<0.005	<0.005	0.01
Molybdenum (Mo)	mg/kg	-	-	<0.1	<0.1	0.3
Nickel (Ni)	mg/kg	-	-	2.64	1.01	7.85
Phosphorus (P)	mg/kg	-	-	<50	<50	137
Potassium (K)	mg/kg	-	-	<100	<100	740
Selenium (Se)	mg/kg	-	-	<0.2	<0.2	<0.2

Values in ***bold italics*** indicate concentrations exceeding guidelines;

[1] Guideline is for residential/parkland course (median grain size > 75 µm) surface soils (CCME 2008).

[2] PAH toxicity not calculated; all PAH results were below detection limit.

[3] Values represent percent difference from control observations.

Table 19 (Cont'd.)

Variable	Units	Guideline		Sampling Location		
		ISQG	PEL	LZ-INLET	LZ-COMP	PZ-1
Total Metals (Cont'd.)						
Silver (Ag)	mg/kg	-	-	<0.1	<0.1	<0.1
Sodium (Na)	mg/kg	-	-	<50	<50	69
Strontium (Sr)	mg/kg	-	-	6.53	8.82	24.90
Sulfur (S)	mg/kg	-	-	<1000	<1000	<1000
Thallium (Tl)	mg/kg	-	-	<0.050	<0.050	0.052
Tin (Sn)	mg/kg	-	-	<2	<2	<2
Titanium (Ti)	mg/kg	-	-	18.1	15.6	74.6
Tungsten (W)	mg/kg	-	-	<0.5	<0.5	<0.5
Uranium (U)	mg/kg	-	-	0.074	0.070	0.319
Vanadium (V)	mg/kg	-	-	1.67	1.47	14.70
Zinc (Zn)	mg/kg	123	315	<2.0	<2.0	11.5
Zirconium (Zr)	mg/kg	-	-	1.2	1.1	9.6

Values in ***bold italics*** indicate concentrations exceeding guidelines;

[1] Guideline is for residential/parkland course (median grain size > 75 μm) surface soils (CCME 2008).

[2] PAH toxicity not calculated; all PAH results were below detection limit.

[3] Values represent percent difference from control observations.

3.3.3.3 Sublethal Toxicity

Results of sublethal toxicity testing on the amphipod *Hyalella azteca* and the midge *Chironomus dilutes* are summarized in Table 20, Figure 22, and Figure 23. A single control group was used for both basins in 2018.

The Lake sediments that were sampled in August 2018 did not cause an ecologically significant decrease in invertebrate survival when compared to the laboratory control, with only one out of five *Hyalella* replicates for the littoral and the pelagic stations showing a greater than 20% decrease in survivorship.

The littoral zone composite (LZ-COMP) and the littoral zone below the inlet (LZ-INLET) samples did not affect the growth of *Hyalella* or chironomids relative to the control; however, sediments from the pelagic station (PZ-1) exhibited decreased *Hyalella* growth in all five replicates (average decrease of 33%), which represents an ecologically significant difference based on Environment Canada's guidelines for comparisons between exposure and control samples (CCME 1995). Pelagic sediments did not show a similar effect on chironomid growth, relative to laboratory controls. Chemical characterization of PZ-1 sediments did not document any exceedances of GoA (2018) or CCME (2008) guidelines for total metals, PAHs, or hydrocarbons, suggesting sediment quality at this station is suitable for biological colonization.

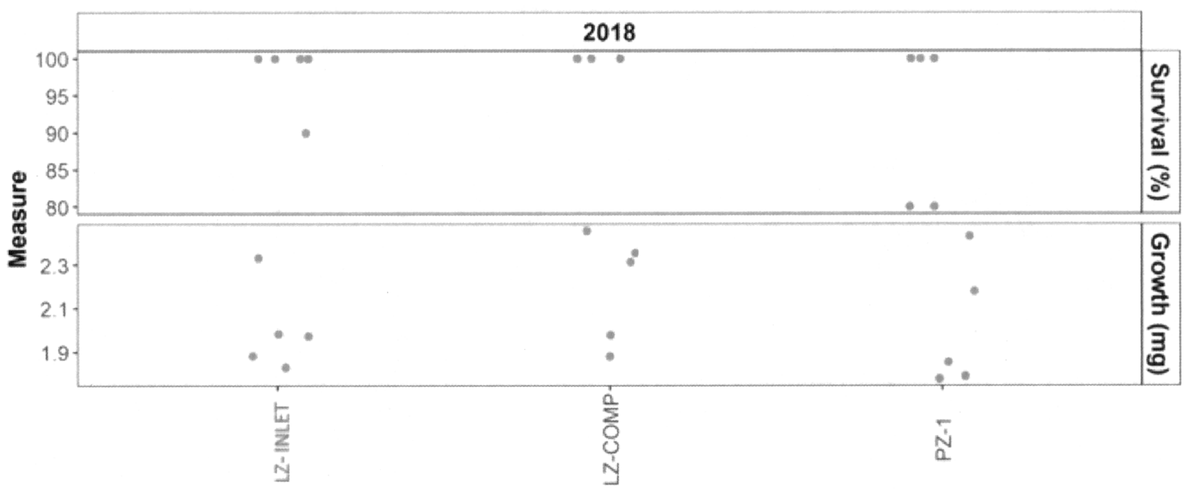
Table 20 Results for Mean Hyalella azteca and Chironomus dilutus Survival and Growth.

Sample ID	Mean Survival% +/- SD	Mean Dry Weight +/- SD (mg)
Hyalella azteca		
Laboratory Control	100 +/- 0	0.21 +/- 0.02
Pelagic Station (PZ-1)	90 +/- 7	0.14 +/- 0.02*
Inlet Channel (LZ-INLET)	98 +/- 4	0.24 +/- 0.04
Littoral Zone (LZ-COMP)	96 +/- 9	0.23 +/- 0.04
Chironomus dilutes		
Laboratory Control	96 +/- 5	1.94 +/- 0.16
Pelagic Station (PZ-1)	92 +/- 11	2.01 +/- 0.29
Inlet Channel (LZ-INLET)	98 +/- 4	2.00 +/- 0.20
Littoral Zone (LZ-COMP)	100 +/- 0	2.20 +/- 0.25

SD = Standard Deviation

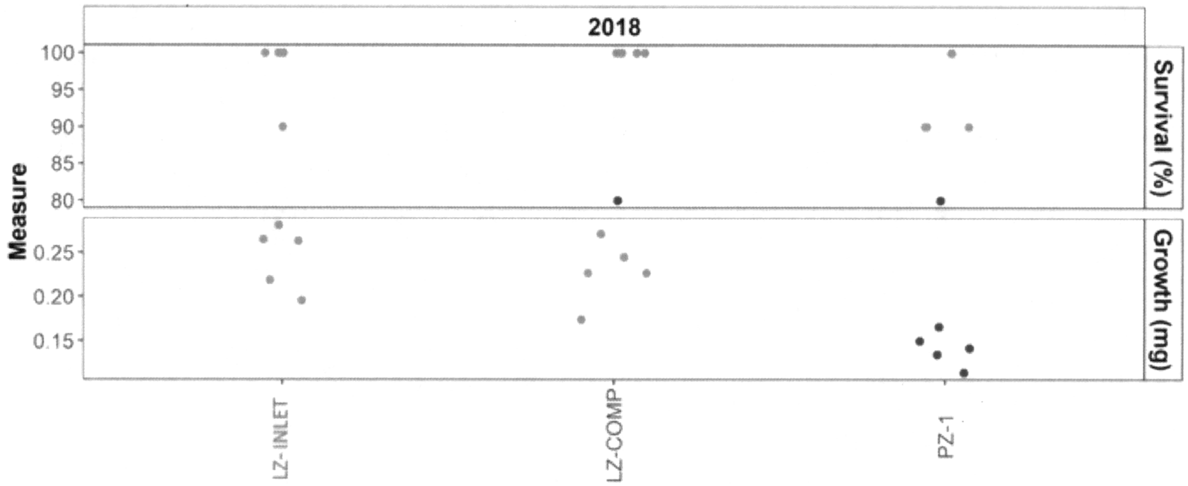
*Indicates a statistically significant decrease in the sample relative to the laboratory control.

Figure 22 *Chironomus dilutus* survival and growth during 10-day static exposure to sediments from the LZ-INLET, LZ-COMP, and the PZ-1 stations of Mrs. T's Lake, August 2018.



Toxicity endpoints (i.e., survival and growth) more than 20% different from the mean of parallel control assays are labelled with green symbols.

Figure 23 ***Hyalella Azteca*** **survival and growth during 14-day static exposure to sediments from the LZ-INLET, the LZ-COMP, and the PZ-1 stations of the Lake, August 2018.**



Toxicity endpoints (i.e., survival and growth) more than 20% different from the mean of parallel control assays are labelled with green symbols.

3.3.4 Fish Passage

A condition of DFO Authorization ED-05-3287-2 requires fish habitat assessments to be performed as part of the Mrs. T's Lake Monitoring Program. These habitat assessments include monitoring the availability of fish passage between Muskeg River and the Lake. Requirements listed in the NNLP (Shell 2013) and the Lake Detailed Design (Norwest 2013) specify water depths of approximately 10 cm are required for fish passage to occur through the inlet and outlet channels of Mrs. T's Lake, although some forage fish species are expected to be able to migrate through shallower depths. While flow velocities for fish passage were not specified in the NNLP or Detailed Design, measured velocities in the inlet and outlet channels are discussed below. The effect of water velocities on upstream fish passage are affected by various site-specific factors, such as the species and life-stages of interest, the distance of travel, and the availability of velocity shadows for mid-travel resting. A general rule of thumb that has been applied for upstream movement assessments is that flow velocities below 0.5 m/s are ideal, and that passage becomes more restricted as velocities increase, with limitations occurring at flow velocities above 1.0 m/s (depending on fish species, swimming form, and size).

Flows in the inlet channel were present for 226 consecutive days during the 2018 WY, beginning on March 20, 2018; however, due to low water depths and ice cover in the channel, fish passage would likely not have been available until higher flows occurred in conjunction with open-water conditions. Open-water flows were present beginning on April 14, 2018 and were maintained for the remainder of the 2018 WY (201 consecutive days). Pressure transducer readings from station IC-1 indicate that inlet channel water depths were continuously greater than 10 cm from April 14 until the end of the 2018 WY. Following Lake filling, all measured flow velocities were also below 1.0 m/s, suggesting upstream fish passage from the Lake to Muskeg River would not have been substantially impeded by high inlet velocities. Field observations during the 2018 WY also indicated that no debris or obstructions were present in the channel that would prevent

fish passage, and no fish stranding or mortalities were observed by Hatfield or Canadian Natural OPS Environment staff.

Flow was measured in the outlet channel for a total of 37 days during the 2018 WY. Pressure transducer readings for station OC-1 indicated that water depths met or exceeded 10 cm in the outlet channel on 32 of those days (May 4-21, July 3-12, and July 26-29). During the May 10 field visit (i.e., near the peak flow period for OC-1 in 2018), the average flow velocity was approximately 0.21 m/s. The outlet channel substrate is also interspersed with large embedded boulders, which provide instream cover and flow complexities (eddies) that are expected to further facilitate fish passage. No obstructions to fish passage were observed in the outlet channel during the 2018 WY. Overall, conditions within the outlet channel were suitable for fish passage for 27 days during the 2018 WY. Consistent with the inlet channel, no fish stranding or mortalities were observed.

3.3.5 Geomorphic Stability of Inlet and Outlet Channels

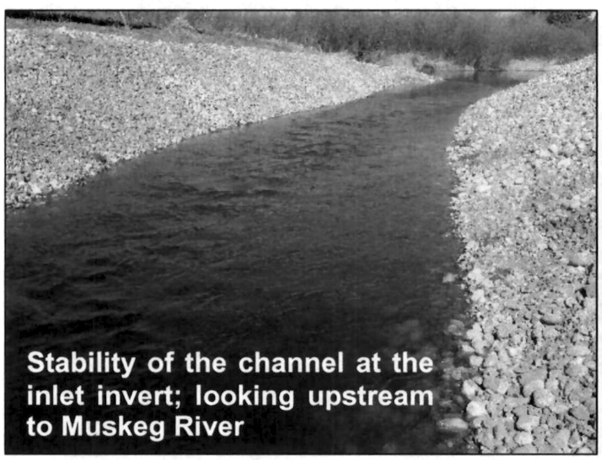
An objective of the Program is to assess the geomorphic stability of the inlet and outlet channels and the lakeshore. The inlet channel conveyed surface flow for 226 days, while the outlet channel received flow contributions from the Lake for 37 days in 2018. Assessing the stability of the outlet channel at select cross-section locations was considered unnecessary in 2018, due to the low magnitude of flows observed (maximum instantaneous discharge of 0.14 m^3/s); however, cross-sections were surveyed in support of developing a stage-discharge relationship for the OC-1 station, and these data and survey locations will be used in future stability assessments. Assessment of the stability of the lakeshore was also considered unnecessary in 2018, as the Lake did not reach FSL until May, and the Year One monitoring objectives were not initiated until July 2018. Monitoring of lakeshore stability will begin in 2019 as part of the Year Two monitoring objectives.

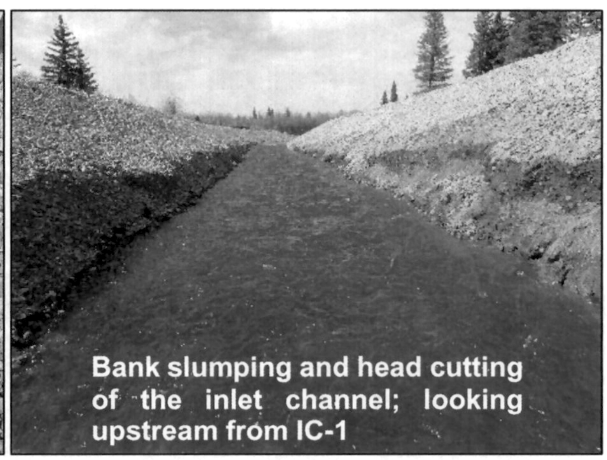
Following March 2018 excavation repairs to the Inlet Invert and channel, as-built drawings (Four Directions Resources 2018) indicated the adjusted elevations were approximately 277.45 m for the Invert and 277.40 m at the IC-1 station (0+090 m). Freshet flows in April caused a large amount of channel erosion and head cutting through the length of the inlet channel. On April 27, the thalweg of the inlet channel was surveyed in multiple locations along the channel length, extending from the IC-1 station up to just below the Inlet Invert at the Muskeg River. The surveyed elevations presented in Table 21 indicate that the Inlet Invert was largely stable (i.e. changed by less than 10 cm from the March 2018 as-built) during these floods, and that erosion (i.e., head cutting of the channel) increased with distance downstream. The survey indicated that as of April 27, 2018, the inlet channel at IC-1 had been eroded by approximately 0.6 m relative to the post-repair as-built elevation. Figure 24 below shows the absence of apparent erosion at the new post-erosion Inlet Invert, the slumping of inlet channel banks, and head cutting along the inlet channel, as observed on April 27. Inlet channel bed elevations collected at IC-1 on June 5 indicate a thalweg elevation of 276.99 m at the IC-1 location (0+090 m). The slight increase in elevation relative to April 27 may suggest material from the slumping channel banks had deposited on the channel bed. A September 18 survey of the Inlet Invert yielded an elevation of 277.41 m, which when compared the as-built and April 27 elevations, demonstrated the stability of the Inlet Invert throughout 2018 (total change of -0.04 m from the as-built). The stability of the inlet channel will continue to be monitored at the Inlet Invert and IC-1 locations in future years.

Table 21 Inlet channel thalweg elevations surveyed on April 27, 2018.

Survey ID	2018 As-Built Approximate Location (m)	Elevation m asl	Coordinates (UTM NAD 83)	
			Easting (m)	Northing (m)
1	0+090 (at IC-1 hydrometric station)	276.805	472077	6347413
2	0+080	276.894	472071	6347420
3	0+075	276.988	472068	6347425
4	0+065	277.094	472064	6347435
5	0+055	277.135	472057	6347443
6	0+040	277.352	472048	6347455
7	0+032	277.366	472046	6347463
8	0+026	277.364	472042	6347468
9	0+020 (at Inlet Invert)	277.364	472041	6347478
10	0+012	277.266	472041	6347486
11	0+008	277.227	472041	6347489

Figure 24 Inlet Channel erosion observed on April 27, 2018.


Stability of the channel at the inlet invert; looking upstream to Muskeg River


Bank slumping and head cutting of the inlet channel; looking upstream from IC-1

4.0 CONCLUSIONS

The following results and conclusions are considered relevant to the 2018 monitoring objectives for the Lake:

- The Lake filled to FSL on May 4, 2018. Filling of the Lake ended the 2018 TDL and initiated Year One of the 5-Year Monitoring Plan.

- Daily discharge data for the inlet channel indicated that 2,916,346 m^3 was diverted from Muskeg River to the Lake over the course of 226 days, from March 20 to the end of the 2018 WY (October 31). Of this volume, 1,609,805 m^3 was diverted under the 2018 TDLs that were issued for Lake filling purposes. Flow inputs to the Lake were much higher than in 2016 or 2017, due to repairs that reduced the Inlet Invert elevation in March 2018.

- Diversions exceeded 15% of Muskeg River flows (42.4% maximum) on 24 days. The diversion total of 1,609,805 m^3 from the beginning of the 2018 WY (November 1, 2017) to the date of Lake filling (May 4, 2018) was below the allocated volume of 1,790,259 m^3, and instantaneous diversion rates did not exceed the 2.36 m^3/s threshold at any time (maximum observed diversion rate of 1.87 m^3/s).

- The estimated Lake volume at the end of the 2018 WY was 2,064,838 m^3 (90% of FSL volume), representing a 1,507,412 m^3 increase from the start of the 2018 WY.

- Filling of the Lake resulted in flows spilling to the outlet channel during the 2018 WY. Daily discharge data for the outlet channel indicated that 142,560 m^3 of water was returned to the Muskeg River over 37 days during the 2018 WY (May 4-20, July 4-11, and July 27-28).

- The results of the water balance suggest that despite an overall increase in Lake volume, there were also substantial volume losses from the Lake in the form of unmeasured outputs. Surface water inputs (inlet channel) and unmeasured outputs (assumed to be shallow groundwater, subsurface flow, reverse flow in the inlet channel, and/or volume unaccounted for in the Lake storage due to outdated bathymetry data) appeared to be the dominant contributors to changes in Lake storage volumes, while precipitation, evaporation, and surface water outputs (outlet channel) comprised smaller proportions of the balance.

- The inlet channel and Inlet Invert were repaired (excavated) in March 2018, lowering the elevation of the entire channel. Freshet flows in April 2018 subsequently caused substantial channel erosion and head cutting in the inlet channel, resulting in bed scour as high as 0.6 m. Subsequent elevation surveys of key locations in the inlet channel indicated that channel elevation stabilized after the freshet event. The geomorphic stability of the outlet channel was not assessed in 2018, due to presence of only intermittent flow (37 days) with low discharge magnitudes (less than 0.2 m^3/s).

- The sustained flow and continuous depths greater than 10 cm in the inlet channel, and the intermittent flow in the outlet channel suggest that fish passage between Muskeg River and the Lake was available in 2018.

- Results of continuous and in situ water quality monitoring indicated that the lake was thermally stratified during the summer months. DO concentrations in the Lake were below guidelines for the

protection of aquatic life (GoA 2018) at depths greater than 4 m until seasonal mixing occurred in fall. pH remained within guidelines during the open-water period. Concentrations of all analytical water quality variables except iron and boron were below guidelines for the protection of aquatic life (GoA 2018) in 2018. These exceedances are considered representative of naturally occurring conditions in the local study area, with similar observations commonly occurring in the Muskeg River watershed.

- 2018 sediment toxicity test results indicated that pelagic sediments had an ecologically significant effect on the growth of *Hyalella*; however, all sediment quality analytes were below the interim sediment quality guidelines and probable effect levels in 2018, and there were no toxic effects on invertebrate survival observed in the lab testing, suggesting the Lake sediments are capable of supporting a diverse community of aquatic invertebrates.
- It is expected that future years of monitoring will show the water and sediment quality in the Lake slowly shifting towards the typical characteristics of a lentic system.

5.0 RECOMMENDATIONS

The following recommendations are proposed to continue and improve the monitoring program at MRME Compensation Lake in 2019:

- Complete monitoring as defined for Year Two of the 5-Year Plan;
- Continue to photo-document in-channel vegetation and beaver activity in the Muskeg River, and rill erosion around the Lake;
- Monitor erosion in the Inlet Channel, especially following freshet floods in 2019;
- Conduct multiple flow measurements along the lengths of the inlet and outlet channels to develop an understanding of flow volumes that may be traveling subsurface or through the substrate;
- Calculate 2019 Lake depths and volumes using updated bathymetry data collected by Canadian Natural; and
- Consider the use of local groundwater level data to inform the calculation of residual water volume contributions to the Lake water balance.

6.0 REFERENCES

[AER] Alberta Energy Regulator. 2017a. Licence to temporarily divert water, Province of Alberta Water Act, R.S.A. 2000, c.W-3 as amended. Licence No. 00394627.

AER Alberta Energy Regulator. 2017b. Licence to temporarily divert water, Province of Alberta Water Act, R.S.A. 2000, c.W-3 as amended. Licence No. 00410160.

Alberta Environment. 2007. Approval, Province of Alberta, Environmental Protection and Enhancement Act, R.S.A. 2000, c.E-12, as amended. Approval No. 20809-01-00.

Alberta Environment. 2008. "Muskeg River Interim Management Framework for Water Quantity and Quality. Management Guidance for Aquatic Components of the Muskeg River Watershed June 2008. aep.alberta.ca/water/programs-and-services/river-management-frameworks.

[AESRD] Alberta Environment and Sustainable Resource Development. 2013. Evaporation and Evapotranspiration in Alberta.

AENV. 2001. Alberta soil and water quality guidelines for hydrocarbons at upstream oil and gas facilities. Edmonton AB.

Baktoft H, Jacobsen L, Skov C, Koed A, Jepsen N, Berg S, Boel M, Aarestrup K, Svendsen JC. 2016. Phenotypic variation in metabolism and morphology correlating with animal swimming activity in the wild: relevance for the OCLTT (oxygen-and capacity-limitation of thermal tolerance), allocation and performance models. Conservation Physiology, *4*(1).

Barnes HH. 1967. "Roughness Characteristics of Natural Channels". US Government Publishing Office.

[BC MOE] BC Ministry of Environment. 2009. Manual of British Columbia Hydrometric Standards. Version 1.0. Prepared by: Ministry of Environment Science and Information Branch for the Resources Information Standards Committee. March 2009.

BC MOE. 2015. British Columbia Approved Water Quality Guidelines: aquatic Life, Wildlife & Agriculture. Summary Report. Water Protection & Sustainability Branch. May 2015.

Casselman JM, Lewis CA. 1996. Habitat requirements of northern pike (*Esox Lucius*). Can. J. Fish Aquat. Sci. 53(Suppl.1): 161-174.

CCME. 1995. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Available from: http://ceqg-rcqe.ccme.ca/download/en/226/

CCME. 1999. Canadian Environmental Quality Guidelines for the Protection of Aquatic Life for dissolved oxygen. Available from: http://ceqg-rcqe.ccme.ca/download/en/177

CCME. 2011. Canadian water quality guidelines for the protection of aquatic life. Canadian Council of Ministers of the Environment, updated 2011.

CCME. 2008. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil. Canadian Council of Ministers of the Environment, updated January 2008.

C1 – Aurora Climate Station data obtained from: http://www.ramp-alberta.org/JOSMP/Location/Detail?locationId=C1

CNRL. 2018. MRME Compensation Lake. Geoeye 1:50 cm image, May 2018. Provided by Canadian Natural Resources Limited.

[ECCC] Environment and Climate Change Canada. 2018. Water level and flow. https://wateroffice.ec.gc.ca/index_e.html.

[DFO] Fisheries and Oceans Canada. 2013. Fisheries Act Authorization amendment for the Muskeg River Mine Expansion Project. Authorization No. ED-05-3287-2.

Four Directions Resources. 2018. CNRL Albian Sands Muskeg River Mine Compensation Lake Inlet repair – as-built. Map provided by Canadian Natural Resources Limited.

[GoA] Government of Alberta. 2018. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta.

Hatfield Consultants. 2013. Muskeg River Mine Expansion – 2012 Fish and Fish Habitat Monitoring Program. Prepared on behalf of Shell Canada Energy.

Hatfield Consultants. 2015. Regional Aquatics Monitoring in support of the Joint Oil Sands Monitoring Plan – Final 2014 report. Prepared for Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA).

Hatfield Consultants. 2016. Muskeg River Mine Expansion Compensation Lake 5-Year Monitoring Plan. Prepared for: Shell Canada Energy. April 2016.

Hatfield Consultants. 2017. Muskeg River Mine Expansion Compensation Lake computed Inlet Channel invert elevation. Prepared for Canadian Natural Resources Limited. October 2017.

Hatfield Consultants. 2018. MRME Compensation Lake Hydrometric Monitoring Report. Prepared for Canadian Natural Resources Limited. April 2018.

Havas M, Rosseland BO. 1995. Response of zooplankton, benthos, and fish to acidification: an overview. Water, Air, and Soil Pollution, 85(1), pp.51-62.

Hood JL, Roy JW, Hayashi M. 2006. Importance of groundwater in the water balance of an alpine headwater Lake. Geophys. Res. Lett. 33. L13405. doi:10.1029/2006GL026611. http://onlinelibrary.wiley.com/doi.10.1029/2006GL026611/full

Inskip PD. 1982. Habitat suitability index models: northern pike. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.17. 40pp

[JOSMP] Joint Oilsands Monitoring Program. 2016 *in progress*. JOSMP 2015 Technical Report. Prepared for AEMERA by Hatfield Consultants, Kilgour and Associates Ltd., Klohn Crippen Berger Ltd., and Western Resource Solutions.

Klug JL, Fischer JM, Ives AR, Dennis B. 2000. Compensatory dynamics in planktonic community responses to pH perturbations. Ecology, 81(2), pp.387-398.

Massengill R. 2017. Stormy Lake Northern Pike Distribution and Movement Study to Inform Future Eradication Efforts. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services.

Moiseenko TI, Sharova ON. 2006. Physiological mechanisms of degradation of fish populations in acidified water bodies. Russian Journal of Ecology, *37*(4), pp.257-263.

Neff JM, Stout SA, Gunster DG. 2004. Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Sediments: Identifying Sources and Ecological Hazard. Integrated Environmental Assessment and Management 1:22-33.

Norwest Corporation. 2013. "MRMe Compensation Lake Detailed Design Report – Final".

Norwest Corporation. 2016. "MRMe Compensation Lake Construction Close-Out Report".

Norwest Corporation. 2017. "Review of HEC-RAS Modeled Results versus 2016 Filling Observations for the MRMe Compensation Lake."

RAMP [Internet]. 2016. Regional Aquatics Monitoring Program – Monitoring Database; [cited 2016 February 23]. Available from: http://www.ramp-alberta.org/ramp.aspx

Scott DM, Lucas MC, Wilson RW. 2005. The effect of high pH on ion balance, nitrogen excretion and behaviour in freshwater fish from a eutrophic lake: a laboratory and field study. Aquatic Toxicology, *73*(1), pp.31-43.

Siefert RE, Spoor WA. 1974. Effects of reduced oxygen on embryos and larvae of the white sucker, coho salmon, brook trout and walleye. Pp. 487-95. In the Early Life History of Fish, editor JHS Blaxter. Springer-Verlag. Berlin, Germany.

Smale MA, Rabeni CF. 1995. Hypoxia and hypothermia tolerances of headwater stream fishes. Transactions of the American Fisheries Society, 125:5.

Shell Canada Energy. 2013. "Muskeg River Mine Expansion No Net Loss Plan – Revision".

[USEPA] United States Environmental Protection Agency. 2004. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures.

[USGS] United States Geological Survey. 1982. Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge. By S.E. Rantz et al. Geological Survey Water Supply Paper 2175. United States Government Printing Office, Washington.

[WSC] Water Survey of Canada. 2001. Hydrometric Technician Career Development Program [Internet]. [cited February 27, 2014]. Available from: http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=DA898EF4-9F6C-486F-95DF-3D79109915C8

WSC. 2013. Measuring discharge with acoustic Doppler current profilers from a moving boat, version adapted for Water Survey of Canada.

Wetzel RG. 2001. Limnology – Lake and River Ecosystems Third Edition. Academic Press. San Diego, California.

APPENDICES

Appendix A1

Quality Assurance and Quality Control

A1.0 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

Quality assurance and quality control (QA/QC) is a documentation system used to review and audit data management and reporting activities. The objective of this system is to provide assurance that defined standards of quality are being achieved. Quality control refers to the specific methodological techniques that are implemented within the quality assurance plan. A successfully implemented QA/QC program will ensure that field and analytical methods are undertaken in a scientifically defensible and repeatable manner. A variety of quality control procedures were applied during the 2018 Program, with the objective of providing incremental checks and balances throughout data collection, data analysis, and reporting.

Hatfield maintains standard operating procedures (SOPs) for field data collection activities, to ensure standardized approaches are used by all Hatfield personnel. These documents identify specific methods for sample collection, sample labeling and handling, equipment calibration and use, and record-keeping. All Hatfield field technicians are familiar with the SOPs, and implement field programs according to the instructions presented within them.

In advance of each sampling program, a set of field work instructions (FWI) was provided to and reviewed by each crew member. These documents consist of a detailed summary of the sampling tasks to be undertaken and the rationale for collecting the data. A pre-field meeting was held by the project manager before each sampling program to review the FWI. This approach allowed any discrepancies in understanding to be identified and addressed prior to data collections.

Quality control procedures for data entry included a 100% re-check on all hardcopy data, to ensure accurate transcription from field data sheets to digital formats. Data were also displayed graphically to visually assess for the presence of any outliers caused by field data entry errors.

Water Quality QA/QC

To assess potential contamination occurring in the field, samples of deionized water were prepared and submitted blind to the consulting laboratories for analysis alongside the ambient water samples. Laboratory-prepared travel blanks were also submitted for each water quality program, to identify potential contamination issues related to laboratory handling and analysis.

Screening for potentially contaminated samples was achieved by comparing field blank results to analytical detection limits. Blanks with analyte concentrations below or near the detection limits represent samples that were collected and handled properly. Blanks with contaminant concentrations greater than five times the detection limits were identified as potentially contaminated during sample collection, shipping, or analysis. The pH analyte was exempt from this quality check since the pH of pure water can not be related to the precision of the instrument.

A review of field and travel blank results was conducted to identify any variables that occurred at elevated levels, and to determine whether incidences of potential contamination resulted during sample collection (i.e., elevated concentrations in field blanks only), or during laboratory analysis (i.e., elevated concentrations in field and travel blanks, or travel blanks only).

Additionally, one set of duplicate samples was collected from the lake outlet in July and September 2018 sampling events and submitted blind to the laboratories. The purpose of collecting duplicate samples is to measure within-site and analytical variability. Analytical results for duplicate samples were compared, and the relative percent difference (RPD; difference between data values and average of data values multiplied by 100%) was calculated for each analyte. Relative percent differences greater than 20% were flagged as providing a potentially unacceptable level of precision; however, because precision decreases as the analyte concentration approaches the detection limit, relative percent differences greater than 20% were considered to be of significance only if analyte concentrations in both samples were greater than five times the detection limit. The 20% RPD target for duplicate samples is identical to QA thresholds used internally by contracted laboratories for most variables measured, although acceptable internal laboratory RPDs for some organic compounds (e.g., CCME hydrocarbons and some PAHs) may be higher (30 to 40%).

Consulting laboratories incorporated a number of additional QA/QC procedures to ensure that sample contamination did not occur during analysis and that the reported results were precise and accurate. A method blank, consisting of a deionized water sample prepared at the initiation of the analysis, was used to assess potential instrument contamination. A sample divided into two aliquots (split sample) was used to assess the precision of the analysis. Spiked samples, reference standards, and laboratory controls were used to establish the accuracy of the analysis.

In addition to quality control of the analytical process, the following field procedures were used to prevent contamination during sample collections:

- All sample bottles were provided, sterilized, by the respective consulting laboratories;
- Field staff wore powder-free nitrile gloves while collecting sample water;
- Surface water samples were collected from approximately 0.3 m below the lake surface, to ensure no floating contaminants or LNAPLs were collected at concentrations unrepresentative of the entire lake water column;
- Near-bottom water was collected using a clean, triple-rinsed Van Dorn sampler, with samples transferred directly to lab-supplied bottles;
- Care was taken not to disturb sediments during sampling, by avoiding bottom contact with the Van Dorn sampler; and
- DO titrations were completed in the field to confirm the accuracy of meter readings.

Sediment Toxicity QA/QC

In 2018, all sediment toxicity testing was conducted by Maxxam Analytics. Each sample was taken from homogenized sediment collected using the sediment quality QA/QC procedures outlined in section Appendix A1.0 – *Sediment Quality QA/QC*. The toxicological laboratory (Maxxam) used a number of laboratory QA/QC procedures to ensure that the reported results for sediment tests were precise and accurate. For each set of tests, a control group and reference toxicant were used to assess the accuracy of the toxicity test. In addition, five replicates of each treatment group were used in each test, to assess the precision of the results.

All laboratory QA/QC sample results were reviewed using in-house laboratory protocols to assess potential contamination and the precision and accuracy of the analyses. Any deviations from QA/QC criteria were identified in the laboratory reports. No deviations were reported during survival and growth analysis for both *Chironomus dilutus* and *Hyalella Azteca* test organisms.

Sediment Quality QA/QC

A number of QA/QC procedures were followed in the field to prevent sediment sample contamination. Before sample collection, all equipment (spoons, pans, grabs) were cleaned using four steps:

1. Equipment was cleaned with ambient water and a metals-free soap (i.e., Liquinox);
2. Equipment was rinsed with environmental grade hexane;
3. Equipment was rinsed with environmental grade acetone (steps 2 and 3 remove any organic residues); and
4. Equipment was rinsed three times with ambient water.

Only grab samples that did not contain foreign objects, obtained an adequate penetration depth, and were not overfilled or leaking were used. Sediments were transferred directly from the grab to a pan, where they were homogenized with a large spoon. All sampling equipment that came in direct contact with the sample was constructed from stainless steel. As an additional precaution, staff wore powder-free nitrile gloves throughout the equipment cleaning and sample collection process.

One split sample was taken from PZ-1 to assess laboratory precision. The relative percent difference (RPD) in the analytes measured in the two samples was calculated, and those that exceeded 20% (when concentrations were greater than five times the detection limit in both samples) were considered to exhibit potentially unacceptable levels of imprecision. The exception to this was the texture of the soil.

A1.1 RESULTS AND DISCUSSION

A1.1.1 Water Quality

A1.1.1.1 Trip Blank Samples

Trip blank results are summarized in (Table A1.1.1) No analytes exceeded the QA/QC guideline of 5 times the method detection limit for trip blank samples collected during summer and fall sampling events.

Table A1.1 Concentrations of water quality analytes in trip blanks for the MRS. T'S Lake 2018.

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			07-Jul-18	13-Sep-18
Conventional Variables				
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2	<2
Alkalinity, Total (as $CaCO_3$)	mg/L	2	<2	<2
Color, True	C.U.	2	<2	<2
Conductivity (EC)	µS/cm	2	<2	<2
Dissolved Organic Carbon	mg/L	0.5	<0.5	<0.5
Hardness (as $CaCO_3$)	mg/L	-	<1	<1
pH	pH units	0.1		
Total Dissolved Solids	mg/L	12*	<10	<12
Total Organic Carbon	mg/L	0.5	<0.5	<0.5
Total Suspended Solids	mg/L	3	<3	<3
Dissolved Metals				
Aluminum (Al)	mg/L	0.001	<0.001	0.0012
Antimony (Sb)	mg/L	0.0001	<0.0001	<0.0001
Arsenic (As)	mg/L	0.0001	<0.0001	<0.0001
Barium (Ba)	mg/L	0.0001	0.00022	<0.0001
Beryllium (Be)	mg/L	0.0001	<0.0001	<0.0001
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.01*	0.0093	<0.01
Cadmium (Cd)	mg/L	0.000005	<0.000005	<0.000005
Calcium (Ca)	mg/L	0.5	<0.5	<0.5
Cesium (Cs)	mg/L	0.00001	<0.00001	-
Chromium (Cr)	mg/L	0.0001	<0.0001	<0.0001
Cobalt (Co)	mg/L	0.0001	<0.0001	<0.0001
Copper (Cu)	mg/L	0.0002	<0.0002	<0.0002
Iron (Fe)	mg/L	0.01	<0.01	<0.01
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.001	<0.0010	-
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Manganese (Mn)	mg/L	0.0001	<0.0001	<0.0001
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0005	<0.0005	<0.0005
Phosphorus (P)	mg/L	0.05	<0.05	-
Potassium (K)	mg/L	0.5	<0.5	<0.5
Rubidium (Rb)	mg/L	0.0002	<0.0002	-
Selenium (Se)	mg/L	0.00005	<0.00005	<0.00005
Silicon (Si)	mg/L	0.05	<0.05	<0.05
Silver (Ag)	mg/L	0.00001	0.00001	<0.00001
Sodium (Na)	mg/L	1	<1	<1
Strontium (Sr)	mg/L	0.0002	<0.0002	<0.0002
Sulfur (S)	mg/L	0.5	<0.5	-

#	Analytics > 5 times the detection limit
#	Analytics < 5 times the detection limit
-	No value provided in lab report
*	Parameter has multiple detection limits - value provided is the greater detection limit

Table A1.1 (Cont’d.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			07-Jul-18	13-Sep-18
Dissolved Metals (Cont’d.)				
Tellurium (Te)	mg/L	0.0002	<0.0002	-
Thallium (Tl)	mg/L	0.00001	<0.00001	<0.00001
Thorium (Th)	mg/L	0.0001	<0.0001	-
Tin (Sn)	mg/L	0.0001	<0.0001	<0.0001
Titanium (Ti)	mg/L	0.0003	<0.0003	<0.0003
Tungsten (W)	mg/L	0.0001	<0.0001	-
Uranium (U)	mg/L	0.00001	<0.00001	<0.00001
Vanadium (V)	mg/L	0.0005	<0.0005	<0.0005
Zinc (Zn)	mg/L	0.001	<0.001	<0.001
Zirconium (Zr)	mg/L	0.0003	<0.0003	-
General Organics				
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1	<1
Naphthenic Acids	mg/L	0.1	0.33	<0.1
Phenols (4AAP)	mg/L	0.001	<0.001	<0.001
Major Ions				
Bicarbonate (HCO_3)	mg/L	5	<5	<5
Calcium (Ca)	mg/L	0.5	-	<0.1
Carbonate (CO_3)	mg/L	5	<5	<5
Chloride (Cl)	mg/L	0.5	<0.5	<0.5
Hydroxide (OH)	mg/L	5	<5	<5
Magnesium (Mg)	mg/L	0.1	-	<0.1
Potassium (K)	mg/L	0.5	-	<0.5
Sodium (Na)	mg/L	1	-	<1
Sulfate (SO_4)	mg/L	0.3	<0.3	<0.3
Sulfide (as S)	mg/L	0.0015	-	<0.0015
Nutrients and BOD				
Ammonia, Total (as N)	mg/L	0.05	<0.05	<0.05
Biochemical Oxygen Demand	mg/L	2	<2	-
Nitrate (as N)	mg/L	0.02	<0.02	<0.02
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022	<0.022
Nitrite (as N)	mg/L	0.01	<0.01	<0.01
Orthophosphate (as P)	mg/L	0.01	<0.010	<0.010
Phosphorus (P)-Total	mg/L	0.001	<0.001	<0.001
Phosphorus (P)-Total Dissolved	mg/L	0.001	<0.001	<0.001
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	<0.2
Total Metals				
Aluminum (Al)	mg/L	0.003	<0.003	<0.003
Antimony (Sb)	mg/L	0.0001	<0.0001	<0.0001
Arsenic (As)	mg/L	0.0001	<0.0001	<0.0001
Barium (Ba)	mg/L	0.0001	0.00023	<0.0001
Beryllium (Be)	mg/L	0.0001	<0.00010	<0.0001
Bismuth (Bi)	mg/L	0.00005	<0.00005	<0.00005
Boron (B)	mg/L	0.002	0.0079	<0.002
Cadmium (Cd)	mg/L	0.000005	0.0000066	<0.000005

#	Analytics > 5 times the detection limit
#	Analytics < 5 times the detection limit
-	No value provided in lab report
*	Parameter has multiple detection limits - value provided is the greater detection limit

Table A1.1 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Trip Blank	
			07-Jul-18	13-Sep-18
Total Metals (Cont'd.)				
Calcium (Ca)	mg/L	0.1*	<0.05	<0.10
Cesium (Cs)	mg/L	0.00001	<0.00001	<0.00001
Chromium (Cr)	mg/L	0.0001	<0.0001	<0.0001
Cobalt (Co)	mg/L	0.0001	<0.0001	<0.0001
Copper (Cu)	mg/L	0.0005	<0.0005	<0.0005
Iron (Fe)	mg/L	0.03*	<0.01	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005	<0.00005
Lithium (Li)	mg/L	0.001	<0.001	<0.001
Magnesium (Mg)	mg/L	0.1	<0.005	<0.1
Manganese (Mn)	mg/L	0.005	<0.0001	<0.0050
Molybdenum (Mo)	mg/L	0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	0.0005	<0.0005	<0.0005
Phosphorus (P)	mg/L	0.05	<0.05	<0.05
Potassium (K)	mg/L	0.5	<0.05	<0.50
Rubidium (Rb)	mg/L	0.0002	<0.0002	<0.0002
Selenium (Se)	mg/L	0.00005	<0.00005	<0.00005
Silicon (Si)	mg/L	0.1	<0.1	<0.1
Silver (Ag)	mg/L	0.00001	<0.00001	<0.00001
Sodium (Na)	mg/L	1*	<0.05	<1
Strontium (Sr)	mg/L	0.0002	<0.0002	<0.0002
Sulfur (S)	mg/L	0.5	<0.5	<0.5
Tellurium (Te)	mg/L	0.0002	<0.0002	<0.0002
Thallium (Tl)	mg/L	0.00001	<0.00001	<0.00001
Thorium (Th)	mg/L	0.0001	<0.0001	<0.0001
Tin (Sn)	mg/L	0.0001	<0.0001	<0.0001
Titanium (Ti)	mg/L	0.0003	<0.0003	<0.0003
Tungsten (W)	mg/L	0.0001	<0.0001	<0.0001
Uranium (U)	mg/L	0.00001	<0.00001	<0.00001
Vanadium (V)	mg/L	0.0005	<0.0005	<0.0005
Zinc (Zn)	mg/L	0.003	<0.003	<0.003
Zirconium (Zr)	mg/L	0.00006	<0.00006	<0.00006

#	Analytics > 5 times the detection limit
#	Analytics < 5 times the detection limit
-	No value provided in lab report
*	Parameter has multiple detection limits - value provided is the greater detection limit

A1.1.1.2 Field Blank Samples

Field blank results are summarized in (Table A1.1). No analytes exceeded the QA/QC guideline of 5 times the method detection limit for field blank samples collected during the fall sampling event.

Table A1.2 Concentrations of water quality analytes in field blanks for the MRS. T'S Lake 2018.

Variable	Unit	Detection Limit	Concentrations in Field Blank 13-Sep-18
Conventional Variables			
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	<2
Alkalinity, Total (as $CaCO_3$)	mg/L	2	<2
Color, True	C.U.	2	<2
Conductivity (EC)	µS/cm	2	<2
Dissolved Organic Carbon	mg/L	0.5	0.56
Hardness (as $CaCO_3$)	mg/L	-	<1
pH	pH	0.1	5.23
Total Dissolved Solids	mg/L	12	<12
Total Organic Carbon	mg/L	0.5	<0.5
Total Suspended Solids	mg/L	3	<3
Dissolved Metals			
Aluminum (Al)	mg/L	0.001	<0.001
Antimony (Sb)	mg/L	0.0001	<0.0001
Arsenic (As)	mg/L	0.0001	<0.0001
Barium (Ba)	mg/L	0.0001	<0.0001
Beryllium (Be)	mg/L	0.0001	<0.0001
Bismuth (Bi)	mg/L	0.00005	<0.00005
Boron (B)	mg/L	0.002	<0.002
Cadmium (Cd)	mg/L	0.000005	<0.000005
Calcium (Ca)	mg/L	0.5	<0.5
Chromium (Cr)	mg/L	0.0001	<0.0001
Cobalt (Co)	mg/L	0.0001	<0.0001
Copper (Cu)	mg/L	0.0002	<0.0002
Iron (Fe)	mg/L	0.01	<0.010
Lead (Pb)	mg/L	0.00005	<0.00005
Magnesium (Mg)	mg/L	0.1	<0.1
Manganese (Mn)	mg/L	0.0001	<0.0001
Mercury (Hg)	ug/L	0.0005	<0.0005
Molybdenum (Mo)	mg/L	0.00005	<0.00005
Nickel (Ni)	mg/L	0.0005	<0.0005
Potassium (K)	mg/L	0.5	<0.5
Selenium (Se)	mg/L	0.00005	<0.00005
Silicon (Si)	mg/L	0.05	<0.05
Silver (Ag)	mg/L	0.00001	<0.00001
Sodium (Na)	mg/L	1	<1
Strontium (Sr)	mg/L	0.0002	<0.0002

#	Analytics< 5 times the detection limit.
#	Analytics > 5 times the detection limit.
-	No value provided in lab report

Table A1.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank 13-Sep-18
Dissolved Metals (Cont'd.)			
Thallium (Tl)	mg/L	0.00001	<0.00001
Tin (Sn)	mg/L	0.0001	<0.0001
Titanium (Ti)	mg/L	0.0003	<0.0003
Uranium (U)	mg/L	0.00001	<0.00001
Vanadium (V)	mg/L	0.0005	<0.0005
Zinc (Zn)	mg/L	0.001	<0.001
General Organics			
Hydrocarbons, Recoverable (I.R.)	mg/L	1	<1
Naphthenic Acids	mg/L	0.1	<0.1
Phenols (4AAP)	mg/L	0.001	<0.001
Major Ions			
Bicarbonate (HCO_3)	mg/L	5	<5.0
Calcium (Ca)	mg/L	0.1	<0.1
Carbonate (CO_3)	mg/L	5	<5
Chloride (Cl)	mg/L	0.5	<0.5
Hydroxide (OH)	mg/L	5	<5
Magnesium (Mg)	mg/L	0.1	<0.1
Potassium (K)	mg/L	0.5	<0.5
Sodium (Na)	mg/L	1	<1
Sulphate (SO_4)	mg/L	0.3	<0.3
Sulphide (as S)	mg/L	0.0015	<0.0015
Nutrients and BOD			
Ammonia, Total (as N)	mg/L	0.05	<0.05
Biochemical Oxygen Demand	mg/L	2	-
Nitrate (as N)	mg/L	0.02	<0.02
Nitrate and Nitrite (as N)	mg/L	0.022	<0.022
Nitrite (as N)	mg/L	0.01	<0.01
Orthophosphate-Dissolved (as P)	mg/L	0.01	<0.01
Phosphorus (P)-Total	mg/L	0.001	<0.001
Phosphorus (P)-Total Dissolved	mg/L	0.001	<0.001
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2
Total Metals			
Aluminum (Al)	mg/L	0.003	<0.003
Antimony (Sb)	mg/L	0.0001	<0.0001
Arsenic (As)	mg/L	0.0001	<0.0001
Barium (Ba)	mg/L	0.0001	<0.0001
Beryllium (Be)	mg/L	0.0001	<0.0001
Bismuth (Bi)	mg/L	0.00005	<0.00005
Boron (B)	mg/L	0.002	<0.002
Cadmium (Cd)	mg/L	0.000005	<0.000005
Calcium (Ca)	mg/L	0.1	<0.1
Cesium (Cs)	mg/L	0.00001	<0.00001
Chromium (Cr)	mg/L	0.0001	<0.0001

#	Analytics< 5 times the detection limit.
#	Analytics > 5 times the detection limit.
-	No value provided in lab report

Table A1.2 (Cont'd.)

Variable	Unit	Detection Limit	Concentrations in Field Blank 13-Sep-18
Total Metals (Cont'd.)			
Cobalt (Co)	mg/L	0.0001	<0.0001
Copper (Cu)	mg/L	0.0005	<0.0005
Iron (Fe)	mg/L	0.03	<0.03
Lead (Pb)	mg/L	0.00005	<0.00005
Lithium (Li)	mg/L	0.001	<0.001
Magnesium (Mg)	mg/L	0.1	<0.1
Manganese (Mn)	mg/L	0.005	<0.005
Mercury (Hg)	µg/L	0.0005	<0.0005
Molybdenum (Mo)	mg/L	0.00005	<0.00005
Nickel (Ni)	mg/L	0.0005	<0.0005
Phosphorus (P)	mg/L	0.05	<0.05
Potassium (K)	mg/L	0.5	<0.5
Rubidium (Rb)	mg/L	0.0002	<0.0002
Selenium (Se)	mg/L	0.00005	<0.00005
Silicon (Si)	mg/L	0.1	<0.1
Silver (Ag)	mg/L	0.00001	<0.00001
Sodium (Na)	mg/L	1	<1
Strontium (Sr)	mg/L	0.0002	<0.0002
Sulfur (S)	mg/L	0.5	<0.5
Tellurium (Te)	mg/L	0.0002	<0.0002
Thallium (Tl)	mg/L	0.00001	<0.00001
Thorium (Th)	mg/L	0.0001	<0.0001
Tin (Sn)	mg/L	0.0001	<0.0001
Titanium (Ti)	mg/L	0.0003	<0.0003
Tungsten (W)	mg/L	0.0001	<0.0001
Uranium (U)	mg/L	0.00001	<0.00001
Vanadium (V)	mg/L	0.0005	<0.0005
Zinc (Zn)	mg/L	0.003	<0.003
Zirconium (Zr)	mg/L	0.00006	<0.00006

#	Analytics< 5 times the detection limit.
#	Analytics > 5 times the detection limit.
-	No value provided in lab report

A1.1.1.3 Duplicate Samples

Duplicate sample results are summarized in Table A1.2 Two sets of water quality duplicates were collected in 2018: a summer (July 7, 2018) and a fall (September 13, 2018) sample. The RPDs for all conventional variables, nutrients, major ions and metals were less than 20% for analytes present at greater than five times the detection limit. Exceptions to this includes total dissolved phosphorus (140.53%) in summer and dissolved manganese (Mn) (29.24%) in fall, both of which do not have water quality guidelines. Naphthenic acid (97.44%) and Phenols (40%) analyte groups are the only additional variables that had RPD greater than 20% but these were less than five time the detection limit. These RPDs were less than 5 times the detection limit for these samples.

Table A1.3 Relative percent differences between duplicate water quality samples collected for Outlet, Summer and Fall in the MRS. T'S Lake, 2018.

Variable	Unit	Detection Limit	Summer		Relative Percent Difference (%)[1]	Fall		Relative Percent Difference (%)[1]
			Outlet	Duplicate		Outlet	Duplicate	
Conventional Variables								
Alkalinity, Phenolphthalein (as $CaCO_3$)	mg/L	2	2	2	0.00	2	2	0.00
Alkalinity, Total (as $CaCO_3$)	mg/L	2	154	153	0.65	154	154	0.00
Color, True	C.U.	2	43.9	41.1	6.59	36.6	37.0	1.09
Conductivity (EC)	µS/cm	2	319	319	0.00	316	317	0.32
Dissolved Organic Carbon	mg/L	1	17.2	16.8	2.35	17.3	17.7	2.29
Hardness (as $CaCO_3$)	mg/L	-	149	149	0.00	176	174	1.14
pH	pH	0.1	8.22	8.2	0.24	8.14	8.13	0.12
Total Dissolved Solids	mg/L	10	230	223	3.09	172	184	6.74
Total Organic Carbon	mg/L	1	16.7	16.6	0.60	-	-	-
Total Suspended Solids	mg/L	3	6	6.6	9.52	8.7	10.4	17.80
Dissolved Metals								
Aluminum (Al)	mg/L	0.001	0.005	0.005	0.00	0.0012	0.0012	0.00
Antimony (Sb)	mg/L	0.00001	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Arsenic (As)	mg/L	0.00005	0.0005	0.0005	0.00	0.00037	0.00034	8.45
Barium (Ba)	mg/L	0.0001	0.0402	0.0391	2.77	0.0409	0.0402	1.73
Beryllium (Be)	mg/L	0.000005	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Bismuth (Bi)	mg/L	0.00005	0.00025	0.00025	0.00	0.00005	0.00005	0.00
Boron (B)	mg/L	0.005	0.071	0.072	1.40	0.0686	0.0685	0.15
Cadmium (Cd)	mg/L	0.000005	0.000025	0.000025	0.00	0.000005	0.000005	0.00
Calcium (Ca)	mg/L	0.05	40.2	39.9	0.75	41.4	41.6	0.48
Cesium (Cs)	mg/L	0.000005	0.00005	0.00005	0.00	-	-	-
Chromium (Cr)	mg/L	0.0005	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Cobalt (Co)	mg/L	0.00005	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Copper (Cu)	mg/L	0.0002	0.001	0.001	0.00	0.00034	0.00036	5.71
Iron (Fe)	mg/L	0.03	0.05	0.05	0.00	0.046	0.042	9.09
Lead (Pb)	mg/L	0.00005	0.00025	0.00025	0.00	0.00005	0.00005	0.00
Lithium (Li)	mg/L	0.0002	0.0105	0.0103	1.92	-	-	-
Magnesium (Mg)	mg/L	0.1	11.8	11.9	0.84	12.2	12.3	0.82
Manganese (Mn)	mg/L	0.0001	0.0005	0.0005	0.00	0.00098	0.00073	29.24
Mercury (Hg)	µg/L	0.0005	0.0005	0.0005	0.00	0.0005	0.0005	0.00
Molybdenum (Mo)	mg/L	0.00005	0.00025	0.00025	0.00	0.000329	0.000337	2.40
Nickel (Ni)	mg/L	0.0002	0.0025	0.0025	0.00	0.0009	0.00087	3.39
Phosphorus (P)	mg/L	0.3	0.25	0.25	0.00	-	-	-
Potassium (K)	mg/L	2	1.89	1.89	0.00	2.01	2.01	0.00
Rubidium (Rb)	mg/L	0.00002	0.0013	0.0015	14.29	-	-	-
Selenium (Se)	mg/L	0.0002	0.00025	0.00025	0.00	0.000059	0.000058	1.71
Silicon (Si)	mg/L	0.05	3.3	3.32	0.60	3.54	3.54	0.00

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) were calculated assuming a concentration equal to the detection limit.
Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.
-	No value provided in lab report

Table A1.3 (Cont'd.)

Variable	Unit	Detection Limit	Summer Outlet	Summer Duplicate	Relative Percent Difference (%)[1]	Fall Outlet	Fall Duplicate	Relative Percent Difference (%)[1]
Silver (Ag)	mg/L	0.000005	0.00005	0.00005	0.00	0.00001	0.00001	0.00
Sodium (Na)	mg/L	2	12.4	12.5	0.80	12.7	12.7	0.00
Strontium (Sr)	mg/L	0.00005	0.122	0.124	1.63	0.127	0.129	1.56
Sulfur (S)	mg/L		7.5	7.7	2.63	-	-	-
Tellurium (Te)	mg/L	0.00001	0.001	0.001	0.00	-	-	-
Thallium (Tl)	mg/L	0.000002	0.00005	0.00005	0.00	0.00001	0.00001	0.00
Thorium (Th)	mg/L	0.000005	0.0005	0.0005	0.00	-	-	-
Tin (Sn)	mg/L	0.0002	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Titanium (Ti)	mg/L	0.0002	0.0015	0.0015	0.00	0.0003	0.0003	0.00
Tungsten (W)	mg/L	0.00001	0.0005	0.0005	0.00	-	-	-
Uranium (U)	mg/L	0.000002	0.000202	0.000196	3.02	0.000213	0.000215	0.93
Vanadium (V)	mg/L	0.00005	0.0025	0.0025	0.00	0.0005	0.0005	0.00
Zinc (Zn)	mg/L	0.001	0.005	0.005	0.00	0.001	0.001	0.00
Zirconium (Zr)	mg/L	0.00005	0.0003	0.0003	0.00	-	-	-
General Organics								
Hydrocarbons, Recoverable (I.R.)	mg/L	1	1	1	0.00	1	1	0.00
Naphthenic Acids	mg/L	1	0.33	0.33	0.00	0.1	0.29	97.44
Phenols (4AAP)	mg/L	0.001	0.0017	0.0014	19.35	0.0018	0.0012	40.00
Major Ions								
Bicarbonate (HCO_3)	mg/L	5	188	187	0.53	188	188	0.00
Calcium (Ca)	mg/L	0.5	0	0	0.00	49.5	49	1.02
Carbonate (CO_3)	mg/L	5	5	5	0.00	5	5	0.00
Chloride (Cl)	mg/L	0.5	4.36	4.39	0.69	4.34	4.36	0.46
Hydroxide (OH)	mg/L	5	5	5	0.00	5	5	0.00
Magnesium (Mg)	mg/L	0.1	0	0	0.00	12.7	12.6	0.79
Potassium (K)	mg/L	0.5	0	0	0.00	2.12	2.12	0.00
Sodium (Na)	mg/L	1	0	0	0.00	13.3	13.2	0.75
Sulfate (SO_4)	mg/L	0.3	19.3	19.4	0.52	18.7	18.8	0.53
Sulphide (as S)	mg/L	0.0015	0	0	0.00	0.0015	0.0015	0.00
Nutrients and BOD								
Ammonia, Total (as N)	mg/L	0.05	0.05	0.05	0.00	0.05	0.05	0.00
Biochemical Oxygen Demand	mg/L	2	2	2	0.00	0	0	0.00
Chlorophyll a	ug/L	0.01	1.88	1.96	4.17	3.83	3.55	7.59
Nitrate (as N)	mg/L	0.02	0.02	0.02	0.00	0.02	0.02	0.00
Nitrate and Nitrite (as N)	mg/L	0.022	0.022	0.022	0.00	0.022	0.022	0.00
Nitrite (as N)	mg/L	0.01	0.01	0.01	0.00	0.01	0.01	0.00
Orthophosphate-Dissolved (as P)	mg/L		0.01	0.01	0.00	0.01	0.01	0.00
Phosphorus (P)-Total	mg/L	0.001	0.0139	0.0155	10.88	0.0154	0.0184	17.75
Phosphorus (P)-Total Dissolved	mg/L	0.001	0.0062	0.0355	140.53	0.0106	0.0089	17.44
Total Kjeldahl Nitrogen	mg/L	0.2	0.2	0.2	0.00	0.6	0.66	9.52

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) were calculated assuming a concentration equal to the detection limit. Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.
-	No value provided in lab report

Table A1.3 (Cont'd.)

Variable	Unit	Detection Limit	Summer Outlet	Summer Duplicate	Relative Percent Difference (%)[1]	Fall Outlet	Fall Duplicate	Relative Percent Difference (%)[1]
Total Metals								
Aluminum (Al)	mg/L	0.003	0.083	0.073	12.82	0.0698	0.0714	2.27
Antimony (Sb)	mg/L	0.00003	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Arsenic (As)	mg/L	0.00005	0.0005	0.0005	0.00	0.00037	0.00035	5.56
Barium (Ba)	mg/L	0.0001	0.0429	0.0432	0.70	0.0422	0.0419	0.71
Beryllium (Be)	mg/L	0.000005	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Bismuth (Bi)	mg/L	0.00005	0.00025	0.00025	0.00	0.00005	0.00005	0.00
Boron (B)	mg/L	0.01	-	-	-	0.0751	0.0749	0.27
Cadmium (Cd)	mg/L	0.000005	0.000025	0.000025	0.00	0.000005	0.000005	0.00
Calcium (Ca)	mg/L	0.05	46.2	44.8	3.08	45.2	45.3	0.22
Cesium (Cs)	mg/L	0.000005	0.00005	0.00005	0.00	0.000011	0.000013	16.67
Chromium (Cr)	mg/L	0.0005	0.00065	0.00073	11.59	0.00026	0.00025	3.92
Cobalt (Co)	mg/L	0.00005	0.0005	0.0005	0.00	0.00022	0.0002	9.52
Copper (Cu)	mg/L	0.0005	0.0025	0.0025	0.00	0.0005	0.0005	0.00
Iron (Fe)	mg/L	0.03	0.268	0.246	8.56	0.31	0.313	0.96
Lead (Pb)	mg/L	0.00005	0.00025	0.00025	0.00	0.000089	0.000096	7.57
Lithium (Li)	mg/L	0.0004	0.0116	0.0114	1.74	0.0101	0.0101	0.00
Magnesium (Mg)	mg/L	0.1	12.8	13.2	3.08	11.8	11.7	0.85
Manganese (Mn)	mg/L	0.0002	0.0136	0.0133	2.23	0.0593	0.0593	0.00
Mercury (Hg)	ug/L	0.0005	0.00101	0.001	1.00	0.00098	0.00094	4.17
Molybdenum (Mo)	mg/L	0.00005	0.00028	0.00025	11.32	0.000342	0.000361	5.41
Nickel (Ni)	mg/L	0.0002	0.0025	0.0025	0.00	0.00111	0.00108	2.74
Phosphorus (P)	mg/L	0.3	0.25	0.25	0.00	0.05	0.05	0.00
Potassium (K)	mg/L	2	2.01	2.03	0.99	2.04	2.05	0.49
Rubidium (Rb)	mg/L	0.00002	0.0016	0.0015	6.45	0.00168	0.00157	6.77
Selenium (Se)	mg/L	0.0002	0.00025	0.00025	0.00	0.000052	0.00005	3.92
Silicon (Si)	mg/L	0.05	3.53	3.55	0.56	3.65	3.66	0.27
Silver (Ag)	mg/L	0.000005	0.00005	0.00005	0.00	0.00001	0.00001	0.00
Sodium (Na)	mg/L	2	13.1	13.4	2.26	12.9	12.9	0.00
Strontium (Sr)	mg/L	0.0002	0.14	0.13	7.41	0.126	0.129	2.35
Sulfur (S)	mg/L	0.00001	8.1	7.8	3.77	7.15	7.18	0.42
Tellurium (Te)	mg/L	0.000005	0.001	0.001	0.00	0.0002	0.0002	0.00
Thallium (Tl)	mg/L	0.000005	0.00005	0.00005	0.00	0.00001	0.00001	0.00
Thorium (Th)	mg/L	0.0002	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Tin (Sn)	mg/L	0.0002	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Titanium (Ti)	mg/L	0.00001	0.0017	0.0015	12.50	0.00189	0.00192	1.57
Tungsten (W)	mg/L	0.000002	0.0005	0.0005	0.00	0.0001	0.0001	0.00
Uranium (U)	mg/L	0.00005	0.000214	0.000204	4.78	0.000243	0.000224	8.14
Vanadium (V)	mg/L	0.000005	0.0025	0.0025	0.00	0.0005	0.00051	1.98
Zinc (Zn)	mg/L	0.003	0.015	0.015	0.00	0.003	0.003	0.00
Zirconium (Zr)	mg/L	0.00005	0.0003	0.0003	0.00	0.000295	0.000313	5.92

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable analytes (i.e., < detection limit) were calculated assuming a concentration equal to the detection limit. Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between duplicates but 1 or both concentrations are < 5 times the detection limit.
# (black)	Analytes differ by > 20% between duplicates and concentrations are > 5 times the detection limit.
-	No value provided in lab report

A1.1.2 Sediment Quality

The sediment quality split sample was collected from PZ-1 in August 2018. The RPDs for all physical variables, metals, organics, and polycyclic aromatic hydrocarbons were less than 20%. Exceptions to this include titanium (21.0%), and 4-Bromofluorobenzene (24.9%) (Table A1.4). Although these analytes were above five times the detection limit none of these compounds have sediment quality guidelines. Additionally, F3 (26.4%, F3(26.4%), F4 (25.6%), and Total hydrocarbons had RPDs above 20% but concentrations were less than five times the detection limit (Table A1.4), and did not exceed sediment quality guidelines.

Table A1.4 Relative percent differences between the PZ-1 and split samples collected at the PZ-1 location in the MRS. T'S Lake, August 2018.

Variable	Units	Detection Limit		Result		RPD[1]
		PZ-1	Split	PZ-1	Split	
Total Metals						
Aluminum (Al)	mg/kg	50	50	5,460	5,390	1.3
Antimony (Sb)	mg/kg	0.1	0.1	<0.1	<0.1	0.0
Arsenic (As)	mg/kg	0.1	0.1	1.77	1.81	2.2
Barium (Ba)	mg/kg	0.5	0.5	38.7	36.4	6.1
Beryllium (Be)	mg/kg	0.1	0.1	0.27	0.27	0.0
Bismuth (Bi)	mg/kg	0.2	0.2	<0.2	<0.2	0.0
Boron (B)	mg/kg	5	5	5.9	6.4	8.1
Cadmium (Cd)	mg/kg	0.02	0.02	0.02	0.024	18.2
Calcium (Ca)	mg/kg	50	50	8,870	8,680	2.2
Chromium (Cr)	mg/kg	0.5	0.5	10.4	9.89	5.0
Cobalt (Co)	mg/kg	0.1	0.1	2.92	2.78	4.9
Copper (Cu)	mg/kg	0.5	0.5	4.41	4.15	6.1
Iron (Fe)	mg/kg	50	50	7,900	7,310	7.8
Lead (Pb)	mg/kg	0.5	0.5	4.02	4.15	3.2
Lithium (Li)	mg/kg	2	2	6.4	6.4	0.0
Magnesium (Mg)	mg/kg	20	20	2,490	2,640	5.8
Manganese (Mn)	mg/kg	1	1	102	97.2	4.8
Mercury (Hg)	mg/kg	0.005	0.005	0.01	0.0091	9.4
Molybdenum (Mo)	mg/kg	0.1	0.1	0.3	0.3	0.0
Nickel (Ni)	mg/kg	0.5	0.5	7.85	7.29	7.4
Phosphorus (P)	mg/kg	50	50	137	144	5.0
Potassium (K)	mg/kg	100	100	740	780	5.3
Selenium (Se)	mg/kg	0.2	0.2	<0.2	<0.2	0.0
Silver (Ag)	mg/kg	0.1	0.1	<0.1	<0.1	0.0
Sodium (Na)	mg/kg	50	50	69	70	1.4
Strontium (Sr)	mg/kg	0.5	0.5	24.9	24.5	1.6
Sulfur (S)	mg/kg	1,000	1,000	<1,000	<1,000	0.0
Thallium (Tl)	mg/kg	0.05	0.05	0.052	0.05	3.9
Tin (Sn)	mg/kg	2	2	<2	<2	0.0
Titanium (Ti)	mg/kg	1	1	74.6	92.1	21.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable variables (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.
Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between station and split samples where one or both results are <5x the detection limit.
# (black)	Analytes differ by > 20% between station and split samples where both results are >5x the detection limit.

Table A1.4 (Cont'd.)

Variable	Units	Detection Limit		Result		RPD[1]
		PZ-1	Split	PZ-1	Split	
Total Metals (Cont'd.)						
Tungsten (W)	mg/kg	0.5	0.5	<0.5	<0.5	0.0
Uranium (U)	mg/kg	0.05	0.05	0.319	0.322	0.9
Vanadium (V)	mg/kg	0.2	0.2	14.7	14.4	2.1
Zinc (Zn)	mg/kg	2	2	11.5	11.4	0.9
Zirconium (Zr)	mg/kg	1	1	9.6	9.7	1.0
PAHs						
1-Methylnaphthalene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
2-Methylnaphthalene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Acenaphthene	mg/kg	0.005	0.005	<0.005	<0.005	0.0
Acenaphthylene	mg/kg	0.005	0.005	<0.005	<0.005	0.0
Acridine	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Anthracene	mg/kg	0.004	0.004	<0.004	<0.004	0.0
Benz(a)anthracene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Benzo(a)pyrene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Benzo(b&j)fluoranthene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Benzo(e)pyrene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Benzo(g,h,i)perylene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Benzo(k)fluoranthene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Biphenyl	mg/kg	0.01	0.01	<0.01	<0.01	0.0
C1 Acenaphthenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Benz(a)Anthracenes/Chrysenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Benzofluoranthenes/Benzopyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Biphenyls	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Dibenzothiophenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Fluoranthenes/Pyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Fluorenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C1 Phenanthrenes/Anthracenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Benzofluoranthenes/Benzopyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Biphenyls	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Dibenzothiophenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Fluoranthenes/Pyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Fluorenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Naphthalenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 Phenanthrenes/Anthracenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C2 sub'd B(a)A/chrysene	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C3 Benzanthracenes/Chrysenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C3 Dibenzothiophenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C3 Fluoranthenes/Pyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C3 Fluorenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C3 Naphthalenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable variables (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit.
Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

#	Analytes differ by > 20% between station and split samples where one or both results are <5x the detection limit.
#	Analytes differ by > 20% between station and split samples where both results are >5x the detection limit.

Table A1.4 (Cont'd.)

Variable	Units	Detection Limit		Result		RPD[1]
		PZ-1	Split	PZ-1	Split	
PAHs (Cont'd.)						
C3 Phenanthrenes/Anthracenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C4 Benzanthracenes/Chrysenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C4 Dibenzothiophenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C4 Fluoranthenes/Pyrenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C4 Naphthalenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
C4 Phenanthrenes/Anthracenes	mg/kg	0.04	0.04	<0.04	<0.04	0.0
Chrysene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
d10-Acenaphthene	%	1	1	83.5	93.3	11.1
d10-Phenanthrene	%	1	1	82	92.1	11.6
d12-Chrysene	%	1	1	89.1	99.3	10.8
d8-Naphthalene	%	1	1	77.4	91.4	16.6
Dibenz(a,h)anthracene	mg/kg	0.005	0.005	<0.005	<0.005	0.0
Dibenzothiophene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Fluoranthene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Fluorene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Indeno(1,2,3-cd)pyrene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Naphthalene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Perylene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Phenanthrene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Pyrene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Quinoline	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Retene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
Physical Variables						
% Clay	%	1	1	20	20	0.0
% Clay (<2um)	%	1	1	8.3	5	49.6
% Moisture	%	0.5	0.5	31.3	25.3	21.2
% Sand	%	1	1	59.8	61.8	3.3
% Sand (2.0mm - 0.05mm)	%	1	1	68.6	69.9	1.9
% Silt	%	1	1	20.2	18.2	10.4
% Silt (0.05mm - 2um)	%	1	1	23.1	25.1	8.3
Inorganic Carbon	%	0.05	0.05	0.355	0.319	10.7
Inorganic Carbon (as $CaCO_3$ Equivalent)	%	0.4	0.4	2.95	2.66	10.3
Texture	-	-	-	Sandy loam	Sandy loam	-
Total Carbon by Combustion	%	0.05	0.05	1.06	1	5.8
Total Organic Carbon	%	0.21	0.05	0.71	0.681	4.2
Organic Compounds						
1,4-Difluorobenzene (SS)	%	1	1	82	91	10.4
2-Bromobenzotrifluoride	%	1	1	78.9	77.1	2.3
3,4-Dichlorotoluene (SS)	%	1	1	77	88.4	13.8
4-Bromofluorobenzene (SS)	%	1	1	73.6	94.5	24.9

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable variables (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit. Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

# (grey)	Analytes differ by > 20% between station and split samples where one or both results are <5x the detection limit.
# (black)	Analytes differ by > 20% between station and split samples where both results are >5x the detection limit.

Table A1.4 (Cont'd.)

Variable	Units	Detection Limit		Result		RPD[1]
		PZ-1	Split	PZ-1	Split	
Benzene	mg/kg	0.005	0.005	<0.005	<0.005	0.0
Ethylbenzene	mg/kg	0.01	0.01	<0.01	<0.01	0.0
F1 (C6-C10)	mg/kg	10	10	<10	<10	0.0
F1-BTEX	mg/kg	10	10	<10	<10	0.0
F2 (C10-C16)	mg/kg	20	20	<20	<20	0.0
F2-Naphth	mg/kg	20	20	<20	<20	0.0
F3 (C16-C34)	mg/kg	20	20	23	30	26.4
F3-PAH	mg/kg	20	20	23	30	26.4
F4 (C34-C50)	mg/kg	20	20	34	44	25.6
F4G-SG (GHH-Silica)	mg/kg	500	500	<500	<500	0.0
m+p-Xylene	mg/kg	0.05	0.05	<0.05	<0.05	0.0
o-Xylene	mg/kg	0.05	0.05	<0.05	<0.05	0.0
Toluene	mg/kg	0.05	0.05	<0.05	<0.05	0.0
Total Hydrocarbons (C6-C50)	mg/kg	20	20	57	74	26.0
Xylenes	mg/kg	0.1	0.1	<0.1	<0.1	0.0

[1] Relative percent difference (RPD) = (difference between sample 1 and 2)/(average of sample 1 and 2) x 100%. RPD for undetectable variables (i.e., < detection limit) was calculated assuming a concentration equal to the detection limit. Precision is influenced by how close the analytical value is to the method detection limit. Thus, assessing percent mean differences is valid only for analytical values that are at least five times the detection limit.

#	Analytes differ by > 20% between station and split samples where one or both results are <5x the detection limit.
#	Analytes differ by > 20% between station and split samples where both results are >5x the detection limit.

Adherence to the SOP and conformance to the laboratory QA/QC protocols resulted in the conclusion that sediment quality data met the data quality objectives for the program.

A1.1.3 Sediment Toxicity

Sediment toxicity reports from Maxxam Analytics indicated that samples from the MRS. T'S Lake were received in good condition and *Hyalella* and *Chironomus* testing was initiated on September 25, and September 13th, 2018 respectively, within the six-week hold time. For *Chironomus,* the mean survival and mean dry weight in the controls were above the acceptable values of 70% and 0.6 mg/g, respectively. The mean percent survival and mean dry weight of the controls for *Hyalella* were also above acceptable levels of ≥80 % and ≥0.1 mg/amphipod. Reference toxicity tests conducted by Maxxam as part of their quality assurance protocols indicated that all reference protocols and test criteria for both *Hyalella* and *Chironomus* test organisms were met.

Adherence to the laboratory sampling, shipping and QA/QC protocols resulted in the conclusion that sediment toxicity data met the data quality objectives for the program.

Appendix A2

Surface Water Hydrology Data

Table A2.1 2018 mean daily discharge for station MR-U, Mrs. T's Lake.

Day	Mean Discharge (m^3/s)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	0.143	0.119	0.131	0.152	0.187	0.250	4.229	1.328	2.290	1.880	0.267	0.946
2	0.134	0.114	0.128	0.151	0.185	0.232	4.376	1.178	2.696	1.610	0.291	0.923
3	0.128	0.112	0.131	0.144	0.186	0.227	4.508	1.088	3.121	1.372	0.293	0.905
4	0.122	0.106	0.122	0.142	0.182	0.233	5.193	1.012	3.557	1.174	0.284	0.901
5	0.121	0.112	0.128	0.133	0.187	0.238	6.066	1.016	3.867	1.009	0.268	0.905
6	0.124	0.106	0.137	0.127	0.193	0.252	6.445	1.080	4.027	0.862	0.263	0.891
7	0.123	0.109	0.136	0.119	0.198	0.257	6.632	1.122	4.039	0.751	0.258	0.866
8	0.114	0.109	0.134	0.121	0.206	0.257	6.780	1.074	3.951	0.649	0.252	0.838
9	0.109	0.114	0.141	0.126	0.205	0.258	6.820	1.020	3.835	0.571	0.302	0.806
10	0.118	0.122	0.145	0.137	0.195	0.270	6.817	0.978	3.654	0.492	0.415	0.767
11	0.113	0.143	0.147	0.131	0.186	0.315	6.671	0.966	3.373	0.440	0.515	0.730
12	0.105	0.143	0.145	0.145	0.175	0.362	6.394	0.982	3.036	0.369	0.585	0.694
13	0.111	0.133	0.147	0.149	0.167	0.417	6.034	1.054	2.693	0.310	0.672	0.673
14	0.112	0.133	0.131	0.135	0.160	0.503	5.615	1.224	2.358	0.237	0.780	0.654
15	0.108	0.155	0.139	0.151	0.153	0.613	5.206	1.220	2.058	0.240	0.892	0.639
16	0.117	0.165	0.158	0.154	0.149	0.655	4.831	1.232	1.824	0.268	0.987	0.636
17	0.126	0.172	0.154	0.150	0.142	0.763	4.507	1.221	1.596	0.187	1.069	0.632
18	0.104	0.171	0.160	0.164	0.152	0.955	4.200	1.178	1.373	0.210	1.125	0.638
19	0.098	0.151	0.156	0.179	0.168	1.278	3.898	1.122	1.168	0.190	1.152	0.646
20	0.117	0.149	0.151	0.206	0.172	1.807	3.622	1.039	0.992	0.153	1.159	0.662
21	0.102	0.148	0.151	0.214	0.164	2.507	3.383	0.940	0.926	0.114	1.159	0.667
22	0.103	0.151	0.158	0.196	0.165	3.168	3.175	0.850	1.063	0.116	1.147	0.674
23	0.127	0.150	0.157	0.204	0.173	3.487	2.939	0.800	1.378	0.177	1.124	0.677
24	0.127	0.142	0.160	0.196	0.170	3.704	2.683	0.735	1.772	0.179	1.093	0.676
25	0.116	0.141	0.164	0.203	0.176	3.803	2.460	0.721	2.246	0.164	1.067	0.670
26	0.109	0.146	0.158	0.196	0.185	3.762	2.290	0.715	2.743	0.153	1.044	0.661
27	0.124	0.143	0.152	0.191	0.195	3.779	2.114	0.798	3.065	0.142	1.027	0.654
28	0.124	0.135	0.159	0.188	0.211	3.821	1.970	1.186	3.093	0.167	1.011	0.646
29	0.123	0.125	0.172	-	0.244	3.922	1.815	1.580	2.891	0.177	0.986	0.633
30	0.122	0.123	0.177	-	0.266	4.055	1.665	1.880	2.565	0.179	0.968	0.622
31	-	0.122	0.155	-	0.273	-	1.511	-	2.199	0.215	-	0.618
Minimum Daily	0.098	0.106	0.122	0.119	0.142	0.227	1.511	0.715	0.926	0.114	0.252	0.618
Mean	0.117	0.134	0.148	0.161	0.186	1.538	4.350	1.078	2.563	0.476	0.749	0.727
Maximum Daily	0.143	0.172	0.177	0.214	0.273	4.055	6.820	1.880	4.039	1.880	1.159	0.946

Table A2.2 2018 mean daily discharge for station IC-1, Mrs. T's Lake.

Day	Mean Discharge (m^3/s)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	0	0	0	0	-	0.006	1.053	M	0.102	0.08	0.012	0.028
2	0	0	0	0	-	0.005	1.252	M	0.123	0.071	0.013	0.026
3	0	0	0	0	-	0.005	1.546	M	0.141	0.062	0.013	0.024
4	0	0	0	0	-	0.005	1.806	M	0.159	0.055	0.013	0.023
5	0	0	0	0	-	0.005	1.589	0.051	0.172	0.049	0.014	0.022
6	0	0	0	0	-	0.005	1.229	0.052	0.179	0.043	0.014	0.021
7	0	0	0	0	-	0.005	0.902	0.053	0.18	0.039	0.014	0.019
8	0	0	0	0	-	0.005	0.627	0.053	0.177	0.035	0.014	0.018
9	0	0	0	0	-	0.004	0.4	0.052	0.171	0.032	0.015	0.016
10	0	0	0	0	-	0.007	0.249	0.051	0.163	0.03	0.017	0.014
11	0	0	0	0	-	0.02	0.23	0.05	0.151	0.027	0.019	0.013
12	0	0	0	0	-	0.041	0.221	0.051	0.137	0.025	0.022	0.011
13	0	0	0	0	-	0.073	0.209	0.053	0.123	0.023	0.026	0.01
14	0	0	0	0	-	0.116	0.196	0.056	0.11	0.021	0.031	0.009
15	0	0	0	0	-	0.17	0.182	0.059	0.098	0.02	0.036	0.009
16	0	0	0	0	-	0.235	0.17	0.061	0.088	0.019	0.041	0.008
17	0	0	0	0	-	0.311	0.159	0.062	0.08	0.018	0.045	0.007
18	0	0	0	0	-	0.405	0.149	0.061	0.071	0.016	0.048	0.007
19	0	0	0	0	-	0.523	0.14	0.059	0.063	0.015	0.049	0.007
20	0	0	0	0	0.005	0.672	0.131	0.057	0.057	0.015	0.05	0.007
21	0	0	0	0	0.004	0.845	0.123	0.054	0.054	0.014	0.049	0.007
22	0	0	0	0	0.004	0.994	0.117	0.052	0.056	0.013	0.047	0.007
23	0	0	0	0	0.004	1.103	0.109	0.05	0.063	0.013	0.045	0.008
24	0	0	0	0	0.004	1.226	0.101	0.048	0.077	0.012	0.042	0.007
25	0	0	0	0	0.004	1.142	0.094	0.047	0.095	0.012	0.04	0.007
26	0	0	0	0	0.004	1.037	0.089	0.046	0.114	0.011	0.038	0.007
27	0	0	0	0	0.005	0.993	0.084	0.047	0.127	0.011	0.036	0.007
28	0	0	0	-	0.006	0.983	0.079	0.053	0.127	0.01	0.034	0.007
29	0	0	0	-	0.007	0.979	0.075	0.064	0.118	0.01	0.032	0.007
30	0	0	0	-	0.007	0.994	0.072	0.081	0.106	0.011	0.03	0.007
31	-	0	0	-	0.007	-	M	-	0.092	0.011	-	0.007
Minimum Daily	0	0	0	0	0.004	0.004	0.072	0.046	0.054	0.010	0.012	0.007
Mean	0	0	0	0	0.005	0.430	0.446	0.055	0.115	0.027	0.030	0.012
Maximum Daily	0	0	0	0	0.007	1.226	1.806	0.081	0.180	0.080	0.050	0.028

Note: No data were available for February 28 to March 19, 2018, due to excavation repairs in the Inlet Channel at this time.

Table A2.3 2018 mean daily discharge for station OC-1, Mrs. T's Lake.

Day	Mean Discharge (m^3/s)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	-	-	-	-	-	0	0	0	0	0	0	0
2	-	-	-	-	-	0	0	0	0	0	0	0
3	-	-	-	-	-	0	0.001	0	0.007	0	0	0
4	-	-	-	-	-	0	0.041	0	0.017	0	0	0
5	-	-	-	-	-	0	0.083	0	0.023	0	0	0
6	-	-	-	-	-	0	0.108	0	0.026	0	0	0
7	-	-	-	-	-	0	0.12	0	0.027	0	0	0
8	-	-	-	-	-	0	0.13	0	0.024	0	0	0
9	-	-	-	-	-	0	0.133	0	0.022	0	0	0
10	-	-	-	-	-	0	0.133	0	0.019	0	0	0
11	-	-	-	-	-	0	0.13	0	0.014	0	0	0
12	-	-	-	-	-	0	0.117	0	0.007	0	0	0
13	-	-	-	-	-	0	0.096	0	0.001	0	0	0
14	-	-	-	-	-	0	0.087	0	0	0	0	0
15	-	-	-	-	-	0	0.063	0	0	0	0	0
16	-	-	-	-	-	0	0.049	0	0	0	0	0
17	-	-	-	-	-	0	0.042	0	0	0	0	0
18	-	-	-	-	-	0	0.036	0	0	0	0	0
19	-	-	-	-	-	0	0.027	0	0	0	0	0
20	-	-	-	-	-	0	0.017	0	0	0	0	0
21	-	-	-	-	-	0	0.008	0	0	0	0	0
22	-	-	-	-	-	0	0.004	0	0	0	0	0
23	-	-	-	-	-	0	0.001	0	0	0	0	0
24	-	-	-	-	-	0	0	0	0	0	0	0
25	-	-	-	-	-	0	0	0	0	0	0	0
26	-	-	-	-	-	0	0	0	0.004	0	0	0
27	-	-	-	-	-	0	0	0	0.011	0	0	0
28	-	-	-	-	-	0	0	0	0.012	0	0	0
29	-	-	-	-	-	0	0	0	0.008	0	0	0
30	-	-	-	-	-	0	0	0	0.002	0	0	0
31	-	-	-	-	-	-	0	-	0	0	-	0
Minimum Daily	-	-	-	-	-	-	0	0	0	0	0	0
Mean	-	-	-	-	-	-	0.046	0	0.007	0	0	0
Maximum Daily	-	-	-	-	-	-	0.133	0	0.027	0	0	0

Table A2.4 2018 daily water elevation for station LL-1, Mrs. T's Lake.

Day	Water Level (m)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	271.124	271.202	271.191	271.238	271.285	272.063	277.308	277.697	277.964	277.930	277.576	277.718
2	271.127	271.204	271.217	271.226	271.243	272.101	277.644	277.667	278.073	277.886	277.550	277.678
3	271.130	271.232	271.218	271.197	271.246	272.102	278.045	277.653	278.145	277.860	277.597	277.719
4	271.128	271.160	271.224	271.264	271.251	272.135	278.301	277.617	278.205	277.831	277.546	277.680
5	271.127	271.259	271.184	271.236	271.248	272.155	278.403	277.638	278.219	277.750	277.595	277.708
6	271.128	271.168	271.209	271.250	271.262	272.107	278.463	277.635	278.230	277.725	277.541	277.709
7	271.126	271.198	271.254	271.268	271.242	272.121	278.455	277.640	278.295	277.724	277.529	277.702
8	271.127	271.172	271.257	271.231	271.222	272.162	278.502	277.642	278.253	277.682	277.560	277.674
9	271.132	271.208	271.236	271.211	271.282	272.182	278.463	277.610	278.229	277.663	277.582	277.659
10	271.127	271.234	271.238	271.295	271.288	272.192	278.466	277.596	278.195	277.651	277.560	277.624
11	271.125	271.173	271.229	271.223	271.273	272.214	278.444	277.629	278.168	277.648	277.629	277.597
12	271.131	271.234	271.184	271.172	271.247	272.248	278.436	277.660	278.116	277.596	277.628	277.683
13	271.127	271.235	271.256	271.297	271.267	272.267	278.400	277.652	278.049	277.553	277.658	277.628
14	271.125	271.154	271.236	271.279	271.250	272.314	278.296	277.676	277.997	277.573	277.695	277.580
15	271.131	271.226	271.168	271.217	271.274	272.407	278.311	277.707	277.938	277.610	277.720	277.652
16	271.133	271.203	271.196	271.253	271.323	272.420	278.258	277.700	277.887	277.541	277.741	277.582
17	271.129	271.222	271.214	271.262	271.401	272.510	278.199	277.702	277.870	277.554	277.754	277.587
18	271.129	271.295	271.209	271.245	271.446	272.625	278.138	277.701	277.813	277.563	277.785	277.648
19	271.139	271.221	271.277	271.268	271.486	272.698	278.095	277.675	277.782	277.548	277.782	277.601
20	271.134	271.201	271.266	271.235	271.616	272.906	278.059	277.669	277.726	277.506	277.794	277.591
21	271.146	271.252	271.225	271.239	271.707	273.168	278.052	277.644	277.718	277.496	277.769	277.655
22	271.115	271.240	271.249	271.240	271.692	273.654	278.014	277.629	277.787	277.538	277.756	277.598
23	271.140	271.234	271.235	271.227	271.744	274.104	277.968	277.627	277.825	277.521	277.731	277.607
24	271.175	271.240	271.230	271.247	271.857	274.633	277.928	277.602	277.917	277.522	277.779	277.616
25	271.191	271.204	271.252	271.271	271.881	275.102	277.892	277.586	278.016	277.516	277.722	277.611
26	271.081	271.196	271.285	271.227	271.938	275.566	277.882	277.581	278.115	277.534	277.782	277.605
27	271.220	271.215	271.258	271.280	271.963	275.919	277.844	277.609	278.160	277.496	277.735	277.639
28	271.175	271.249	271.221	271.307	272.043	276.348	277.801	277.675	278.163	277.496	277.720	277.595
29	271.204	271.189	271.147	-	272.020	276.668	277.801	277.746	278.134	277.510	277.736	277.619
30	271.194	271.221	271.302	-	272.040	276.941	277.758	277.829	278.084	277.540	277.682	277.598
31	-	271.185	271.271	-	272.029	-	277.737	-	277.979	277.520	-	277.608
Minimum Daily	271.081	271.154	271.147	271.172	271.222	272.063	277.308	277.581	277.718	277.496	277.529	277.580
Mean	271.141	271.214	271.230	271.247	271.518	273.268	278.108	277.656	278.034	277.616	277.674	277.638
Maximum Daily	271.220	271.295	271.302	271.307	272.043	276.941	278.502	277.829	278.295	277.930	277.794	277.719

Notes: Values are geodetic water surface elevations. Daily mean water elevations are calculated as the average of 15-minute water surface elevations over a 24-hour period.

Table A2.5 2018 daily water elevation for station IC-1, Mrs. T's Lake.

Day	Water Level (m)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	277.618	277.617	277.617	277.617	-	277.275	277.322	-	277.938	277.968	277.545	277.751
2	277.618	277.617	277.617	277.617	-	277.244	277.584	-	278.038	277.915	277.553	277.744
3	277.617	277.617	277.617	277.617	-	277.230	277.946	-	278.119	277.866	277.561	277.739
4	277.617	277.617	277.617	277.617	-	277.231	278.268	-	278.193	277.821	277.567	277.736
5	277.617	277.617	277.617	277.617	-	277.241	278.407	277.641	278.244	277.784	277.569	277.737
6	277.617	277.617	277.617	277.617	-	277.251	278.447	277.645	278.271	277.749	277.570	277.733
7	277.617	277.617	277.617	277.617	-	277.246	278.462	277.655	278.276	277.719	277.570	277.725
8	277.617	277.617	277.617	277.617	-	277.229	278.472	277.656	278.265	277.692	277.570	277.716
9	277.617	277.617	277.617	277.617	-	277.212	278.470	277.647	278.249	277.669	277.583	277.707
10	277.617	277.617	277.617	277.617	-	277.195	278.465	277.638	278.225	277.649	277.590	277.696
11	277.617	277.617	277.617	277.617	-	277.189	278.450	277.633	278.183	277.630	277.611	277.685
12	277.617	277.617	277.618	277.617	-	277.182	278.422	277.638	278.131	277.612	277.637	277.673
13	277.617	277.617	277.617	277.617	-	277.182	278.381	277.650	278.075	277.598	277.665	277.663
14	277.618	277.617	277.617	277.617	-	277.192	278.334	277.670	278.018	277.583	277.699	277.656
15	277.617	277.617	277.617	277.617	-	277.202	278.286	277.696	277.963	277.573	277.736	277.649
16	277.617	277.617	277.617	277.617	-	277.212	278.239	277.710	277.919	277.563	277.771	277.645
17	277.617	277.617	277.617	277.617	-	277.219	278.198	277.713	277.876	277.555	277.794	277.644
18	277.617	277.617	277.617	277.617	-	277.242	278.158	277.706	277.831	277.546	277.806	277.644
19	277.617	277.617	277.617	277.617	-	277.288	278.118	277.695	277.789	277.538	277.812	277.647
20	277.617	277.617	277.617	277.617	277.230	277.359	278.079	277.681	277.750	277.531	277.813	277.651
21	277.617	277.617	277.617	277.617	277.224	277.439	278.045	277.663	277.732	277.525	277.813	277.654
22	277.617	277.617	277.617	277.617	277.215	277.455	278.016	277.646	277.753	277.519	277.810	277.656
23	277.617	277.617	277.617	277.617	277.214	277.392	277.981	277.634	277.805	277.522	277.803	277.658
24	277.617	277.617	277.617	277.617	277.212	277.374	277.941	277.620	277.893	277.522	277.795	277.658
25	277.617	277.618	277.617	277.617	277.215	277.239	277.905	277.608	277.998	277.518	277.787	277.656
26	277.617	277.618	277.617	277.617	277.22	277.128	277.877	277.604	278.103	277.514	277.781	277.653
27	277.617	277.618	277.617	277.617	277.23	277.150	277.847	277.610	278.167	277.510	277.776	277.651
28	277.617	277.618	277.617	-	277.259	277.228	277.822	277.653	278.175	277.508	277.771	277.648
29	277.617	277.618	277.617	-	277.298	277.221	277.796	277.726	278.144	277.514	277.764	277.644
30	277.617	277.618	277.617	-	277.307	277.241	277.777	277.822	278.091	277.523	277.758	277.641
31	-	277.617	277.617	-	277.306	-	-	-	278.027	277.535	-	277.638
Minimum Daily	277.617	277.617	277.617	277.617	277.212	277.128	277.322	277.604	277.732	277.508	277.545	277.638
Mean	277.617	277.617	277.617	277.617	277.244	277.250	278.117	277.664	278.040	277.622	277.696	277.677
Maximum Daily	277.618	277.618	277.618	277.617	277.307	277.455	278.472	277.822	278.276	277.968	277.813	277.751

Notes: Values are geodetic water surface elevations. Daily mean water elevations are calculated as the average of 15-minute water surface elevations over a 24-hour period.

Table A2.6 2018 daily water elevation for station MR-U, Mrs. T's Lake.

Day	Water Level (m)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	277.892	277.83	277.8	277.775	277.761	277.739	278.145	277.707	277.982	277.976	277.589	277.754
2	277.883	277.825	277.797	277.773	277.759	277.727	278.166	277.675	278.058	277.922	277.6	277.746
3	277.874	277.823	277.797	277.767	277.758	277.722	278.185	277.656	278.133	277.871	277.601	277.74
4	277.864	277.817	277.79	277.765	277.755	277.723	278.277	277.64	278.205	277.827	277.597	277.737
5	277.858	277.82	277.793	277.758	277.756	277.723	278.387	277.644	278.255	277.787	277.589	277.737
6	277.854	277.815	277.797	277.752	277.758	277.728	278.432	277.663	278.281	277.749	277.587	277.732
7	277.847	277.816	277.796	277.746	277.76	277.728	278.454	277.676	278.285	277.718	277.584	277.723
8	277.835	277.814	277.793	277.746	277.763	277.726	278.471	277.666	278.274	277.688	277.581	277.714
9	277.827	277.816	277.796	277.748	277.762	277.724	278.476	277.655	278.259	277.665	277.601	277.703
10	277.827	277.821	277.798	277.754	277.754	277.715	278.476	277.646	278.234	277.638	277.642	277.69
11	277.818	277.834	277.798	277.749	277.749	277.709	278.462	277.645	278.193	277.621	277.676	277.678
12	277.806	277.833	277.796	277.757	277.774	277.703	278.433	277.652	278.14	277.595	277.694	277.665
13	277.805	277.825	277.795	277.758	277.795	277.699	278.394	277.673	278.084	277.571	277.717	277.657
14	277.8	277.823	277.784	277.748	277.82	277.704	278.346	277.718	278.026	277.538	277.745	277.65
15	277.794	277.837	277.788	277.757	277.823	277.716	278.297	277.719	277.971	277.542	277.772	277.644
16	277.801	277.841	277.799	277.758	277.759	277.703	278.251	277.725	277.927	277.559	277.792	277.641
17	277.807	277.845	277.795	277.754	277.713	277.71	278.21	277.724	277.881	277.518	277.808	277.639
18	277.791	277.843	277.798	277.761	277.717	277.738	278.169	277.716	277.833	277.533	277.817	277.64
19	277.786	277.829	277.794	277.769	277.724	277.793	278.129	277.705	277.787	277.525	277.823	277.642
20	277.801	277.826	277.789	277.783	277.724	277.883	278.09	277.686	277.744	277.505	277.823	277.648
21	277.79	277.825	277.788	277.786	277.717	277.99	278.056	277.661	277.728	277.481	277.822	277.649
22	277.79	277.825	277.791	277.775	277.715	278.077	278.026	277.639	277.768	277.484	277.818	277.651
23	277.807	277.824	277.789	277.778	277.718	278.102	277.991	277.626	277.846	277.527	277.81	277.652
24	277.808	277.817	277.79	277.773	277.714	278.108	277.95	277.609	277.935	277.53	277.801	277.652
25	277.8	277.815	277.791	277.775	277.715	278.093	277.914	277.607	278.031	277.523	277.793	277.65
26	277.795	277.817	277.786	277.77	277.718	278.076	277.886	277.608	278.123	277.519	277.786	277.647
27	277.84	277.814	277.781	277.766	277.721	278.079	277.856	277.635	278.181	277.514	277.781	277.645
28	277.863	277.808	277.784	277.763	277.728	278.085	277.831	277.741	278.188	277.532	277.775	277.642
29	277.846	277.799	277.791	-	277.743	278.1	277.803	277.834	278.156	277.54	277.767	277.638
30	277.836	277.797	277.792	-	277.752	278.12	277.775	277.9	278.102	277.541	277.761	277.634
31	-	277.795	277.778	-	277.753	-	277.745	-	278.036	277.562	-	277.633
Minimum Daily	277.786	277.795	277.778	277.746	277.713	277.699	277.745	277.607	277.728	277.481	277.581	277.633
Mean	277.825	277.822	277.792	277.763	277.748	277.848	278.164	277.682	278.053	277.616	277.718	277.673
Maximum Daily	277.892	277.845	277.800	277.786	277.823	278.120	278.476	277.900	278.285	277.976	277.823	277.754

Notes: Values are geodetic water surface elevations. Daily mean water elevations are calculated as the average of 15-minute water surface elevations over a 24-hour period.

Table A2.7 2018 daily water elevation for station MR-D, Mrs. T's Lake.

Day	Water Level (m)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	276.713	276.709	276.695	276.678	276.654	276.649	277.313	276.770	277.395	277.382	276.817	276.848
2	276.706	276.704	276.692	276.680	276.655	276.622	277.354	276.744	277.429	277.316	276.806	276.844
3	276.700	276.701	276.693	276.680	276.660	276.614	277.383	276.725	277.491	277.246	276.786	276.838
4	276.695	276.698	276.689	276.684	276.661	276.624	277.460	276.708	277.654	277.176	276.778	276.834
5	276.695	276.701	276.693	276.676	276.661	276.634	277.573	276.738	277.667	277.113	276.769	276.833
6	276.699	276.698	276.697	276.671	276.663	276.676	277.623	276.765	277.689	277.061	276.757	276.830
7	276.699	276.699	276.696	276.667	276.665	276.708	277.639	276.774	277.681	277.021	276.746	276.823
8	276.691	276.698	276.693	276.662	276.667	276.691	277.651	276.770	277.650	276.984	276.743	276.805
9	276.679	276.699	276.694	276.666	276.667	276.626	277.647	276.763	277.586	276.952	276.813	276.799
10	276.680	276.703	276.696	276.667	276.658	276.588	277.635	276.755	277.517	276.920	276.866	276.782
11	276.688	276.711	276.698	276.658	276.652	276.580	277.609	276.756	277.441	276.885	276.883	276.775
12	276.681	276.711	276.698	276.676	276.674	276.579	277.571	276.765	277.357	276.844	276.897	276.769
13	276.680	276.707	276.702	276.683	276.696	276.577	277.522	276.815	277.278	276.802	276.913	276.764
14	276.671	276.704	276.694	276.661	276.729	276.589	277.465	276.850	277.209	276.757	276.908	276.760
15	276.663	276.712	276.697	276.671	276.731	276.613	277.414	276.849	277.155	276.729	276.915	276.763
16	276.671	276.715	276.703	276.672	276.678	276.703	277.363	276.852	277.106	276.695	276.925	276.765
17	276.675	276.716	276.694	276.669	276.622	276.756	277.310	276.847	277.051	276.656	276.927	276.767
18	276.665	276.715	276.694	276.682	276.616	276.765	277.259	276.833	276.996	276.623	276.924	276.773
19	276.663	276.709	276.686	276.693	276.616	276.799	277.212	276.815	276.945	276.606	276.922	-
20	276.678	276.708	276.680	276.692	276.617	276.886	277.174	276.792	276.897	276.606	276.918	-
21	276.672	276.708	276.679	276.695	276.609	277.000	277.135	276.762	276.888	276.617	276.911	-
22	276.673	276.708	276.683	276.682	276.605	277.098	277.098	276.731	277.039	276.617	276.903	-
23	276.687	276.707	276.682	276.688	276.609	277.115	277.054	276.747	277.249	276.654	276.898	-
24	276.688	276.703	276.683	276.678	276.606	277.144	277.012	276.761	277.498	276.664	276.893	-
25	276.683	276.700	276.683	276.679	276.604	277.144	276.971	276.751	277.671	276.662	276.886	-
26	276.680	276.699	276.679	276.673	276.607	277.119	276.943	276.771	277.786	276.658	276.880	-
27	276.710	276.699	276.677	276.670	276.609	277.133	276.918	276.838	277.818	276.655	276.873	-
28	276.729	276.695	276.677	276.661	276.614	277.182	276.892	277.035	277.773	276.674	276.865	-
29	276.720	276.692	276.686	-	276.630	277.232	276.861	277.213	277.682	276.699	276.858	-
30	276.713	276.692	276.692	-	276.645	277.274	276.831	277.333	277.570	276.734	276.850	-
31	-	276.691	276.680	-	276.660	-	276.803	-	277.465	276.798	-	-
Minimum Daily	276.663	276.691	276.677	276.658	276.604	276.577	276.803	276.708	276.885	276.602	276.741	276.760
Mean	276.688	276.704	276.690	276.6756	276.646	276.824	277.280	276.820	277.406	276.829	276.860	276.798
Maximum Daily	276.729	276.716	276.703	276.695	276.731	277.274	277.651	277.332	277.816	277.379	276.926	276.847

Notes: Values are geodetic water surface elevations. Daily mean water elevations are calculated as the average of 15-minute water surface elevations over a 24-hour period.

Table A2.8 2018 daily Lake and water balance component volumes, Mrs. T's Lake.

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
1-Nov-2017	557,426	0	0	0	0	0	0
2-Nov-2017	557,884	458	458	0	0	0	0
3-Nov-2017	558,342	458	458	0	0	0	0
4-Nov-2017	558,037	-306	-306	0	0	0	0
5-Nov-2017	557,884	-153	-153	0	0	0	0
6-Nov-2017	558,037	153	153	0	0	0	0
7-Nov-2017	557,731	-305	-305	0	0	0	0
8-Nov-2017	557,884	153	153	0	0	0	0
9-Nov-2017	558,648	764	764	0	0	0	0
10-Nov-2017	557,884	-764	-764	0	0	0	0
11-Nov-2017	557,578	-305	-305	0	0	0	0
12-Nov-2017	558,495	917	917	0	0	0	0
13-Nov-2017	557,884	-611	-611	0	0	0	0
14-Nov-2017	557,578	-305	-305	0	0	0	0
15-Nov-2017	558,495	917	917	0	0	0	0
16-Nov-2017	558,801	306	306	0	0	0	0
17-Nov-2017	558,189	-611	-611	0	0	0	0
18-Nov-2017	558,189	0	0	0	0	0	0
19-Nov-2017	559,718	1529	1529	0	0	0	0
20-Nov-2017	558,954	-765	-765	0	0	0	0
21-Nov-2017	560,790	1836	1836	0	0	0	0
22-Nov-2017	556,052	-4737	-4737	0	0	0	0
23-Nov-2017	559,871	3819	3819	0	0	0	0
24-Nov-2017	565,238	5366	5366	0	0	0	0
25-Nov-2017	567,699	2461	2461	0	0	0	0
26-Nov-2017	550,878	-16821	-16821	0	0	0	0
27-Nov-2017	571,584	20706	20706	0	0	0	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
28-Nov-2017	565,238	-6346	-6346	0	0	0	0
29-Nov-2017	569,132	3894	3894	0	0	0	0
30-Nov-2017	568,161	-972	-972	0	0	0	0
1-Dec-2017	568,826	665	665	0	0	0	0
2-Dec-2017	569,132	306	306	0	0	0	0
3-Dec-2017	573,426	4294	4294	0	0	0	0
4-Dec-2017	562,935	-10491	-10491	0	0	0	0
5-Dec-2017	577,580	14645	14645	0	0	0	0
6-Dec-2017	564,163	-13417	-13417	0	0	0	0
7-Dec-2017	568,777	4614	4614	0	0	0	0
8-Dec-2017	564,777	-4000	-4000	0	0	0	0
9-Dec-2017	569,745	4968	4968	0	0	0	0
10-Dec-2017	573,733	3988	3988	0	0	0	0
11-Dec-2017	564,930	-8803	-8803	0	0	0	0
12-Dec-2017	573,733	8803	8803	0	0	0	0
13-Dec-2017	573,887	154	154	0	0	0	0
14-Dec-2017	562,015	-11872	-11872	0	0	0	0
15-Dec-2017	572,504	10489	10489	0	0	0	0
16-Dec-2017	568,979	-3525	-3525	0	0	0	0
17-Dec-2017	571,891	2911	2911	0	0	0	0
18-Dec-2017	583,140	11250	11250	0	0	0	0
19-Dec-2017	571,737	-11403	-11403	0	0	0	0
20-Dec-2017	568,673	-3064	-3064	0	0	0	0
21-Dec-2017	576,502	7829	7829	0	0	0	0
22-Dec-2017	574,655	-1846	-1846	0	0	0	0
23-Dec-2017	573,733	-922	-922	0	0	0	0
24-Dec-2017	574,655	922	922	0	0	0	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
25-Dec-2017	569,132	-5523	-5523	0	0	0	0
26-Dec-2017	568,469	-664	-664	0	0	0	0
27-Dec-2017	570,817	2348	2348	0	0	0	0
28-Dec-2017	576,040	5223	5223	0	0	0	0
29-Dec-2017	567,391	-8649	-8649	0	0	0	0
30-Dec-2017	571,737	4346	4346	0	0	0	0
31-Dec-2017	566,775	-4962	-4962	0	0	0	0
1-Jan-2018	567,699	923	923	0	0	0	0
2-Jan-2018	571,124	3425	3425	0	0	0	0
3-Jan-2018	571,277	153	153	0	0	0	0
4-Jan-2018	572,197	920	920	0	0	0	0
5-Jan-2018	566,621	-5576	-5576	0	0	0	0
6-Jan-2018	569,898	3276	3276	0	0	0	0
7-Jan-2018	576,810	6912	6912	0	0	0	0
8-Jan-2018	577,272	462	462	0	0	0	0
9-Jan-2018	574,040	-3231	-3231	0	0	0	0
10-Jan-2018	574,348	307	307	0	0	0	0
11-Jan-2018	572,965	-1383	-1383	0	0	0	0
12-Jan-2018	566,621	-6344	-6344	0	0	0	0
13-Jan-2018	577,118	10496	10496	0	0	0	0
14-Jan-2018	574,040	-3077	-3077	0	0	0	0
15-Jan-2018	564,163	-9878	-9878	0	0	0	0
16-Jan-2018	568,469	4306	4306	0	0	0	0
17-Jan-2018	570,664	2195	2195	0	0	0	0
18-Jan-2018	569,898	-766	-766	0	0	0	0
19-Jan-2018	580,357	10459	10459	0	0	0	0
20-Jan-2018	578,659	-1698	-1698	0	0	0	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
21-Jan-2018	572,351	-6308	-6308	0	0	0	0
22-Jan-2018	576,040	3689	3689	0	0	0	0
23-Jan-2018	573,887	-2153	-2153	0	0	0	0
24-Jan-2018	573,119	-768	-768	0	0	0	0
25-Jan-2018	576,502	3383	3383	0	0	0	0
26-Jan-2018	581,593	5092	5092	0	0	0	0
27-Jan-2018	577,426	-4168	-4168	0	0	0	0
28-Jan-2018	571,737	-5689	-5689	0	0	0	0
29-Jan-2018	560,943	-10794	-10794	0	0	0	0
30-Jan-2018	584,224	23282	23282	0	0	0	0
31-Jan-2018	579,431	-4794	-4794	0	0	0	0
1-Feb-2018	574,348	-5083	-5083	0	0	0	0
2-Feb-2018	572,504	-1843	-1843	0	0	0	0
3-Feb-2018	568,623	-3882	-3882	0	0	0	0
4-Feb-2018	578,351	9728	9728	0	0	0	0
5-Feb-2018	574,040	-4311	-4311	0	0	0	0
6-Feb-2018	576,194	2153	2153	0	0	0	0
7-Feb-2018	578,968	2774	2774	0	0	0	0
8-Feb-2018	573,272	-5696	-5696	0	0	0	0
9-Feb-2018	570,204	-3068	-3068	0	0	0	0
10-Feb-2018	583,140	12936	12936	0	0	0	0
11-Feb-2018	572,044	-11096	-11096	0	0	0	0
12-Feb-2018	564,777	-7267	-7267	0	0	0	0
13-Feb-2018	583,450	18673	18673	0	0	0	0
14-Feb-2018	580,666	-2784	-2784	0	0	0	0
15-Feb-2018	571,124	-9542	-9542	0	0	0	0
16-Feb-2018	576,656	5532	5532	0	0	0	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
17-Feb-2018	578,042	1387	1387	0	0	0	0
18-Feb-2018	575,424	-2618	-2618	0	0	0	0
19-Feb-2018	578,968	3544	3544	0	0	0	0
20-Feb-2018	573,887	-5081	-5081	0	0	0	0
21-Feb-2018	574,501	615	615	0	0	0	0
22-Feb-2018	574,655	154	154	0	0	0	0
23-Feb-2018	572,658	-1997	-1997	0	0	0	0
24-Feb-2018	575,732	3074	3074	0	0	0	0
25-Feb-2018	579,431	3699	3699	0	0	0	0
26-Feb-2018	572,658	-6773	-6773	0	0	0	0
27-Feb-2018	580,821	8163	8163	0	0	0	0
28-Feb-2018	584,999	4179	4179	0	0	0	0
1-Mar-2018	581,593	-3406	-3406	0	0	0	0
2-Mar-2018	575,117	-6477	-6477	0	0	0	0
3-Mar-2018	575,578	462	462	0	0	0	0
4-Mar-2018	576,348	770	770	0	0	0	0
5-Mar-2018	575,886	-462	-462	0	0	0	0
6-Mar-2018	578,042	2157	2157	0	0	0	0
7-Mar-2018	574,963	-3080	-3080	0	0	0	0
8-Mar-2018	571,891	-3072	-3072	0	0	0	0
9-Mar-2018	581,130	9239	9239	0	0	0	0
10-Mar-2018	582,057	928	928	0	0	0	0
11-Mar-2018	579,739	-2318	-2318	0	0	0	0
12-Mar-2018	575,732	-3709	-4008	0	299	0	0
13-Mar-2018	578,813	3381	3082	0	299	0	0
14-Mar-2018	576,194	-2321	-2620	0	299	0	0
15-Mar-2018	579,894	3999	3700	0	299	0	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
16-Mar-2018	587,482	7887	7588	0	299	0	0
17-Mar-2018	599,655	12173	12173	0	0	0	0
18-Mar-2018	606,731	7075	7075	0	0	0	0
19-Mar-2018	613,052	6321	6321	0	0	0	0
20-Mar-2018	633,806	20322	20754	0	0	432	0
21-Mar-2018	648,524	14372	14718	0	0	346	0
22-Mar-2018	646,087	-2782	-2437	0	0	346	0
23-Mar-2018	654,553	8120	8466	0	0	346	0
24-Mar-2018	673,127	18228	18574	0	0	346	0
25-Mar-2018	677,102	3630	3976	0	0	346	0
26-Mar-2018	686,589	9141	9487	0	0	346	0
27-Mar-2018	690,769	3748	4180	0	0	432	0
28-Mar-2018	704,225	12938	13456	0	0	518	0
29-Mar-2018	700,344	-4486	-3881	0	0	605	0
30-Mar-2018	703,719	2769	3374	0	0	605	0
31-Mar-2018	701,862	-2462	-1857	0	0	605	0
1-Apr-2018	707,608	5228	5747	0	0	518	0
2-Apr-2018	714,057	6016	6448	0	0	432	0
3-Apr-2018	714,227	-262	170	0	0	432	0
4-Apr-2018	719,850	5191	5623	0	0	432	0
5-Apr-2018	723,267	2986	3418	0	0	432	0
6-Apr-2018	715,077	-8622	-8190	0	0	432	0
7-Apr-2018	717,462	1952	2384	0	0	432	0
8-Apr-2018	724,465	6572	7004	0	0	432	0
9-Apr-2018	727,893	3082	3428	0	0	346	0
10-Apr-2018	729,610	1112	1717	0	0	605	0
11-Apr-2018	733,224	1886	3614	0	0	1728	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
12-Apr-2018	739,079	2312	5854	0	0	3542	0
13-Apr-2018	742,360	-3026	3281	0	0	6307	0
14-Apr-2018	750,505	-980	8146	0	897	10022	0
15-Apr-2018	766,747	2450	16241	0	897	14688	0
16-Apr-2018	769,030	-18021	2283	0	0	20304	0
17-Apr-2018	784,926	-11214	15895	1136	897	26870	0
18-Apr-2018	805,460	-13561	20534	0	897	34992	0
19-Apr-2018	818,624	-31126	13165	0	897	45187	0
20-Apr-2018	856,687	-19101	38063	0	897	58061	0
21-Apr-2018	905,798	-23001	49110	0	897	73008	0
22-Apr-2018	1,000,308	8821	94510	705	897	85882	0
23-Apr-2018	1,091,817	-2893	91509	0	897	95299	0
24-Apr-2018	1,205,758	8911	113941	0	897	105926	0
25-Apr-2018	1,310,643	7113	104885	0	897	98669	0
26-Apr-2018	1,421,166	21823	110523	0	897	89597	0
27-Apr-2018	1,507,040	976	85874	0	897	85795	0
28-Apr-2018	1,620,585	29511	113545	0	897	84931	0
29-Apr-2018	1,706,035	1761	85450	0	897	84586	0
30-Apr-2018	1,780,466	-10553	74432	0	897	85882	0
1-May-2018	1,948,043	77746	167576	261	1409	90979	0
2-May-2018	2,089,527	34609	141484	111	1409	108173	0
3-May-2018	2,276,896	55291	187370	0	1409	133574	86
4-May-2018	2,348,017	-81452	71121	1486	1409	156038	3542
5-May-2018	2,390,718	-86008	42701	0	1409	137290	7171
6-May-2018	2,416,697	-69466	25979	0	1409	106186	9331
7-May-2018	2,412,599	-70254	-4098	0	1409	77933	10368
8-May-2018	2,433,379	-20926	20780	175	1409	54173	11232

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
		Water Balance Components					
	Lake	GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
9-May-2018	2,416,697	-38341	-16682	0	1409	34560	11491
10-May-2018	2,417,979	-7331	1282	0	1409	21514	11491
11-May-2018	2,407,964	-17246	-10015	0	1409	19872	11232
12-May-2018	2,404,595	-10945	-3369	0	1409	19094	10109
13-May-2018	2,389,458	-23875	-15137	384	1409	18058	8294
14-May-2018	2,345,931	-51535	-43527	0	1409	16934	7517
15-May-2018	2,352,190	-2613	6259	0	1409	15725	5443
16-May-2018	2,330,102	-31133	-22088	0	1409	14688	4234
17-May-2018	2,305,606	-33196	-24497	0	1409	13738	3629
18-May-2018	2,323,229	9270	17624	0	1409	12874	3110
19-May-2018	2,301,672	-29911	-21558	0	1409	12096	2333
20-May-2018	2,283,802	-26310	-17870	0	1409	11318	1469
21-May-2018	2,280,346	-11982	-3456	0	1409	10627	691
22-May-2018	2,261,693	-27007	-18653	0	1409	10109	346
23-May-2018	2,239,354	-30260	-22338	0	1409	9418	86
24-May-2018	2,220,145	-26526	-19209	0	1409	8726	0
25-May-2018	2,203,029	-23829	-17117	0	1409	8122	0
26-May-2018	2,198,303	-12437	-4726	1431	1409	7690	0
27-May-2018	2,180,459	-23692	-17844	0	1409	7258	0
28-May-2018	2,160,486	-25390	-19973	0	1409	6826	0
29-May-2018	2,160,486	-5071	0	0	1409	6480	0
30-May-2018	2,140,744	-24553	-19742	0	1409	6221	0
31-May-2018	2,131,187	-14023	-9557	0	1409	5875	0
1-Jun-2018	2,113,136	-21924	-18051	94	1751	5530	0
2-Jun-2018	2,099,729	-17463	-13407	624	1751	5184	0
3-Jun-2018	2,093,511	-9305	-6218	0	1751	4838	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
4-Jun-2018	2,077,635	-23252	-15876	4634	1751	4493	0
5-Jun-2018	2,086,876	6210	9241	376	1751	4406	0
6-Jun-2018	2,085,552	-4527	-1324	461	1751	4493	0
7-Jun-2018	2,087,759	-621	2207	0	1751	4579	0
8-Jun-2018	2,088,643	-1945	884	0	1751	4579	0
9-Jun-2018	2,074,566	-16818	-14076	0	1751	4493	0
10-Jun-2018	2,068,449	-10016	-6118	1243	1751	4406	0
11-Jun-2018	2,082,909	10157	14460	1734	1751	4320	0
12-Jun-2018	2,096,617	5740	13708	5313	1751	4406	0
13-Jun-2018	2,093,068	-6706	-3549	329	1751	4579	0
14-Jun-2018	2,103,739	7584	10671	0	1751	4838	0
15-Jun-2018	2,117,630	10544	13891	0	1751	5098	0
16-Jun-2018	2,114,483	-6666	-3147	0	1751	5270	0
17-Jun-2018	2,115,381	-2707	899	0	1751	5357	0
18-Jun-2018	2,114,932	-3969	-449	0	1751	5270	0
19-Jun-2018	2,103,293	-14985	-11639	0	1751	5098	0
20-Jun-2018	2,100,619	-5847	-2674	0	1751	4925	0
21-Jun-2018	2,089,527	-14007	-11092	0	1751	4666	0
22-Jun-2018	2,082,909	-12435	-6618	3075	1751	4493	0
23-Jun-2018	2,082,028	-3620	-880	171	1751	4320	0
24-Jun-2018	2,071,067	-13357	-10961	0	1751	4147	0
25-Jun-2018	2,064,094	-13640	-6974	4357	1751	4061	0
26-Jun-2018	2,061,921	-5284	-2173	888	1751	3974	0
27-Jun-2018	2,074,129	-1885	12208	11783	1751	4061	0
28-Jun-2018	2,103,293	21326	29164	5010	1751	4579	0
29-Jun-2018	2,135,276	27520	31983	685	1751	5530	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
30-Jun-2018	2,173,465	32942	38189	0	1751	6998	0
1-Jul-2018	2,237,425	56684	63959	256	1794	8813	0
2-Jul-2018	2,290,732	39343	53307	5131	1794	10627	0
3-Jul-2018	2,326,761	15143	36029	11102	1794	12182	605
4-Jul-2018	2,308,092	-29145	-18668	2	1794	13738	1469
5-Jul-2018	2,313,899	-5273	5806	0	1794	14861	1987
6-Jul-2018	2,318,465	-7116	4566	256	1794	15466	2246
7-Jul-2018	2,345,514	12550	27049	3074	1794	15552	2333
8-Jul-2018	2,328,022	-28918	-17492	1	1794	15293	2074
9-Jul-2018	2,318,049	-21053	-9973	0	1794	14774	1901
10-Jul-2018	2,352,163	23465	34113	0	1794	14083	1642
11-Jul-2018	2,338,407	-23799	-13756	0	1794	13046	1210
12-Jul-2018	2,312,171	-36442	-26236	768	1794	11837	605
13-Jul-2018	2,278,867	-42052	-33304	0	1794	10627	86
14-Jul-2018	2,253,406	-34195	-25460	1024	1794	9504	0
15-Jul-2018	2,224,929	-35152	-28477	1	1794	8467	0
16-Jul-2018	2,200,664	-30074	-24265	0	1794	7603	0
17-Jul-2018	2,192,649	-13134	-8016	0	1794	6912	0
18-Jul-2018	2,166,036	-30953	-26612	0	1794	6134	0
19-Jul-2018	2,151,734	-17952	-14302	0	1794	5443	0
20-Jul-2018	2,126,203	-28748	-25531	85	1794	4925	0
21-Jul-2018	2,122,587	-22803	-3615	16316	1794	4666	0
22-Jul-2018	2,154,033	28401	31445	0	1794	4838	0
23-Jul-2018	2,171,605	2648	17572	11275	1794	5443	0
24-Jul-2018	2,214,898	38092	43293	343	1794	6653	0
25-Jul-2018	2,262,670	40930	47772	427	1794	8208	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
26-Jul-2018	2,311,670	41290	49000	0	1794	9850	346
27-Jul-2018	2,334,348	14450	22679	0	1794	10973	950
28-Jul-2018	2,335,869	-6621	1521	0	1794	10973	1037
29-Jul-2018	2,321,214	-22365	-14655	0	1794	10195	691
30-Jul-2018	2,296,194	-33236	-25020	1024	1794	9158	173
31-Jul-2018	2,244,672	-57678	-51522	1	1794	7949	0
1-Aug-2018	2,221,101	-29159	-23571	0	1324	6912	0
2-Aug-2018	2,200,192	-25720	-20909	0	1324	6134	0
3-Aug-2018	2,187,950	-16360	-12241	85	1324	5357	0
4-Aug-2018	2,174,396	-16982	-13554	0	1324	4752	0
5-Aug-2018	2,137,097	-40209	-37300	0	1324	4234	0
6-Aug-2018	2,125,750	-13737	-11346	0	1324	3715	0
7-Aug-2018	2,125,298	-2498	-452	0	1324	3370	0
8-Aug-2018	2,106,418	-20580	-18880	0	1324	3024	0
9-Aug-2018	2,097,950	-9909	-8468	0	1324	2765	0
10-Aug-2018	2,092,625	-6593	-5325	0	1324	2592	0
11-Aug-2018	2,091,296	-2337	-1328	0	1324	2333	0
12-Aug-2018	2,068,449	-23684	-22848	0	1324	2160	0
13-Aug-2018	2,049,811	-19300	-18637	0	1324	1987	0
14-Aug-2018	2,058,451	8149	8640	0	1324	1814	0
15-Aug-2018	2,074,566	15712	16116	0	1324	1728	0
16-Aug-2018	2,044,652	-30233	-29915	0	1324	1642	0
17-Aug-2018	2,050,242	5359	5591	0	1324	1555	0
18-Aug-2018	2,054,125	3803	3883	21	1324	1382	0
19-Aug-2018	2,047,659	-6502	-6466	64	1324	1296	0
20-Aug-2018	2,029,705	-18011	-17954	85	1324	1296	0
21-Aug-2018	2,025,463	-4128	-4242	0	1324	1210	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
22-Aug-2018	2,043,364	17042	17901	1060	1324	1123	0
23-Aug-2018	2,036,092	-10963	-7272	3892	1324	1123	0
24-Aug-2018	2,036,519	694	427	20	1324	1037	0
25-Aug-2018	2,033,960	-3280	-2559	1008	1324	1037	0
26-Aug-2018	2,041,650	8064	7690	0	1324	950	0
27-Aug-2018	2,025,463	-15813	-16187	0	1324	950	0
28-Aug-2018	2,025,463	460	0	0	1324	864	0
29-Aug-2018	2,031,406	938	5943	5464	1324	864	0
30-Aug-2018	2,044,222	8150	12817	5040	1324	950	0
31-Aug-2018	2,035,665	-8357	-8557	173	1324	950	0
1-Sep-2018	2,059,751	20401	24086	3246	598	1037	0
2-Sep-2018	2,048,520	-11757	-11232	0	598	1123	0
3-Sep-2018	2,068,885	19827	20365	13	598	1123	0
4-Sep-2018	2,046,799	-23708	-22085	1098	598	1123	0
5-Sep-2018	2,068,012	20602	21213	0	598	1210	0
6-Sep-2018	2,044,652	-23973	-23361	0	598	1210	0
7-Sep-2018	2,039,510	-5753	-5142	0	598	1210	0
8-Sep-2018	2,052,829	5876	13320	6832	598	1210	0
9-Sep-2018	2,062,355	8740	9526	88	598	1296	0
10-Sep-2018	2,052,829	-10482	-9526	85	598	1469	0
11-Sep-2018	2,082,909	27803	30079	1233	598	1642	0
12-Sep-2018	2,082,468	-2304	-440	561	598	1901	0
13-Sep-2018	2,095,729	11612	13260	0	598	2246	0
14-Sep-2018	2,112,238	14429	16510	0	598	2678	0
15-Sep-2018	2,123,491	8740	11252	0	598	3110	0
16-Sep-2018	2,133,003	6568	9512	0	598	3542	0
17-Sep-2018	2,138,919	2626	5916	0	598	3888	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
18-Sep-2018	2,153,113	10644	14194	0	598	4147	0
19-Sep-2018	2,151,734	-5014	-1379	0	598	4234	0
20-Sep-2018	2,157,256	1629	5522	171	598	4320	0
21-Sep-2018	2,145,772	-15718	-11484	0	0	4234	0
22-Sep-2018	2,139,831	-9404	-5941	0	598	4061	0
23-Sep-2018	2,128,466	-14655	-11365	0	598	3888	0
24-Sep-2018	2,150,356	18859	21890	0	598	3629	0
25-Sep-2018	2,124,394	-28820	-25962	0	598	3456	0
26-Sep-2018	2,151,734	24484	27340	171	598	3283	0
27-Sep-2018	2,130,279	-23967	-21455	0	598	3110	0
28-Sep-2018	2,123,491	-9129	-6789	0	598	2938	0
29-Sep-2018	2,130,733	4478	7243	0	0	2765	0
30-Sep-2018	2,106,418	-26907	-24315	0	0	2592	0
1-Oct-2018	2,122,587	13750	16169	0	0	2419	0
2-Oct-2018	2,104,632	-20202	-17956	0	0	2246	0
3-Oct-2018	2,123,039	16334	18407	0	0	2074	0
4-Oct-2018	2,105,525	-19502	-17514	0	0	1987	0
5-Oct-2018	2,118,080	10654	12555	0	0	1901	0
6-Oct-2018	2,118,530	-1364	450	0	0	1814	0
7-Oct-2018	2,115,381	-4790	-3149	0	0	1642	0
8-Oct-2018	2,102,847	-14089	-12534	0	0	1555	0
9-Oct-2018	2,096,173	-8057	-6674	0	0	1382	0
10-Oct-2018	2,080,709	-16673	-15464	0	0	1210	0
11-Oct-2018	2,068,885	-12734	-11824	0	214	1123	0
12-Oct-2018	2,106,865	37030	37980	0	0	950	0
13-Oct-2018	2,082,468	-25261	-24397	0	0	864	0
14-Oct-2018	2,061,487	-21546	-20982	0	214	778	0

Table A2.8 (Cont'd.)

Date	Daily Volumes (m^3)						
	Lake	Water Balance Components					
		GW_{in} - GW_{out} (Groundwater residual)	$\Delta_{storage}$ (Change in Lake storage)	P (Precipitation)	E (Lake Evaporation)	Qi_n (IC-1 surface flow inputs)	Q_{out} (OC-1 surface flow outputs)
15-Oct-2018	2,093,068	31017	31581	0	214	778	0
16-Oct-2018	2,062,355	-31404	-30713	0	0	691	0
17-Oct-2018	2,064,529	1782	2173	0	214	605	0
18-Oct-2018	2,091,296	26376	26768	0	214	605	0
19-Oct-2018	2,070,631	-21270	-20665	0	0	605	0
20-Oct-2018	2,066,269	-4752	-4361	0	214	605	0
21-Oct-2018	2,094,398	27737	28128	0	214	605	0
22-Oct-2018	2,069,321	-25468	-25077	0	214	605	0
23-Oct-2018	2,073,253	3455	3932	0	214	691	0
24-Oct-2018	2,077,196	3551	3943	0	214	605	0
25-Oct-2018	2,075,004	-2583	-2192	0	214	605	0
26-Oct-2018	2,072,379	-3017	-2626	0	214	605	0
27-Oct-2018	2,087,317	14548	14939	0	214	605	0
28-Oct-2018	2,068,012	-19910	-19305	0	0	605	0
29-Oct-2018	2,078,512	9895	10500	0	0	605	0
30-Oct-2018	2,069,321	-9796	-9191	0	0	605	0
31-Oct-2018	2,073,691	3765	4370	0	0	605	0
2018 TOTAL	-	**-1157833**	**1516265**	**127962**	**227650**	**2916346**	**142560**

Table A2.9 2018 mean daily water temperature for station IC-1, Mrs. T's Lake Inlet Channel.

Day	Mean Daily Temperature (°C)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	-	-	-	-	-	0.2	6.8	-	18.5	21.1	13.7	6.9
2	-	-	-	-	-	0.2	6.8	-	18.6	21.4	13.5	6.4
3	-	-	-	-	-	0.2	6.9	-	18.6	22.3	13.4	6.2
4	-	-	-	-	-	0.1	7.2	-	18.8	21.3	12.6	5.5
5	-	-	-	-	-	0.1	7.5	15.0	18.9	21.0	12.5	4.9
6	-	-	-	-	-	0.2	8.2	13.7	18.8	21.3	11.7	5.1
7	-	-	-	-	-	0.2	9.2	14.4	18.8	21.2	12.1	4.9
8	-	-	-	-	-	0.2	9.8	16.1	18.3	21.4	12.6	4.8
9	-	-	-	-	-	0.2	9.8	17.9	18.4	21.8	11.3	4.7
10	-	-	-	-	-	0.2	10.1	18.4	19.8	22.1	10.5	4.5
11	-	-	-	-	-	0.2	10.1	17.4	20.5	21.7	10.2	4.5
12	-	-	-	-	-	0.3	10.7	16.5	20.9	20.9	9.6	4.4
13	-	-	-	-	-	0.2	10.7	15.2	21.4	20.1	9.0	4.3
14	-	-	-	-	-	0.2	11.0	14.6	21.0	19.8	8.6	3.7
15	-	-	-	-	-	0.3	11.5	14.7	19.9	20.2	8.5	3.9
16	-	-	-	-	-	0.3	11.4	16.1	20.0	20.0	8.2	4.0
17	-	-	-	-	-	0.2	12.0	17.8	20.4	20.5	8.1	3.8
18	-	-	-	-	-	0.4	12.5	19.2	20.7	20.3	8.2	4.1
19	-	-	-	-	-	0.4	13.9	20.1	20.7	19.6	8.3	3.7
20	-	-	-	-	0.2	0.4	14.7	21.5	20.8	19.5	8.1	3.4
21	-	-	-	-	0.1	0.2	15.8	22.0	20.7	19.6	7.9	3.6
22	-	-	-	-	0.2	0.2	17.0	22.1	19.6	19.6	8.3	3.5
23	-	-	-	-	0.1	0.2	18.1	22.2	17.8	18.2	8.4	3.4
24	-	-	-	-	0.1	0.3	18.8	22.9	17.0	17.1	8.2	4.0
25	-	-	-	-	0.2	0.8	19.5	23.3	17.2	16.0	8.2	4.1
26	-	-	-	-	0.1	2.5	19.5	22.6	17.9	15.4	8.4	4.1
27	-	-	-	-	0.1	3.8	18.7	20.6	18.6	15.1	7.9	4.2
28	-	-	-	-	0.1	5.2	18.6	19.0	19.5	14.8	7.6	4.1
29	-	-	-	-	0.1	6.0	18.0	18.2	20.0	13.9	7.4	4.0
30	-	-	-	-	0.1	6.2	17.1	18.3	20.4	13.9	7.1	4.0
31	-	-	-	-	0.2	-	-	-	20.4	13.7	-	3.9
Minimum Daily	-	-	-	-	0.1	0.1	6.8	13.7	17.0	13.7	7.1	3.4
Mean	-	-	-	-	0.1	1.0	12.7	18.5	19.4	19.2	9.7	4.4
Maximum Daily	-	-	-	-	0.2	6.2	19.5	23.3	21.4	22.3	13.7	6.9

Notes: Daily mean water temperatures are calculated as the average of 15-minute water temperatures over a 24-hour period.

Table A2.10 2018 mean daily water temperature for station OC-1, Mrs. T's Lake Outlet Channel.

Day	Mean Daily Temperature (°C)											
	November	December	January	February	March	April	May	June	July	August	September	October
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	20	-	-	-
3	-	-	-	-	-	-	-0.2	-	20.4	-	-	-
4	-	-	-	-	-	-	0.4	-	21.2	-	-	-
5	-	-	-	-	-	-	1.3	-	21.1	-	-	-
6	-	-	-	-	-	-	2	-	21.7	-	-	-
7	-	-	-	-	-	-	2.3	-	21.1	-	-	-
8	-	-	-	-	-	-	2.5	-	20.1	-	-	-
9	-	-	-	-	-	-	2.6	-	20.4	-	-	-
10	-	-	-	-	-	-	2.8	-	21.4	-	-	-
11	-	-	-	-	-	-	2.9	-	22.7	-	-	-
12	-	-	-	-	-	-	2.9	-	23.1	-	-	-
13	-	-	-	-	-	-	3	-	22.3	-	-	-
14	-	-	-	-	-	-	3.1	-	-	-	-	-
15	-	-	-	-	-	-	3.2	-	-	-	-	-
16	-	-	-	-	-	-	3.3	-	-	-	-	-
17	-	-	-	-	-	-	3.4	-	-	-	-	-
18	-	-	-	-	-	-	3.5	-	-	-	-	-
19	-	-	-	-	-	-	3.7	-	-	-	-	-
20	-	-	-	-	-	-	3.8	-	-	-	-	-
21	-	-	-	-	-	-	3.9	-	-	-	-	-
22	-	-	-	-	-	-	4.1	-	-	-	-	-
23	-	-	-	-	-	-	4.2	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	20.9	-	-	-
27	-	-	-	-	-	-	-	-	21.4	-	-	-
28	-	-	-	-	-	-	-	-	22.3	-	-	-
29	-	-	-	-	-	-	-	-	23.5	-	-	-
30	-	-	-	-	-	-	-	-	22.7	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-
Minimum Daily	-	-	-	-	-	-	-0.2	-	20.0	-	-	-
Mean	-	-	-	-	-	-	2.8	-	21.5	-	-	-
Maximum Daily	-	-	-	-	-	-	4.2	-	23.5	-	-	-

Notes: Daily mean water temperatures are calculated as the average of 15-minute water temperatures over a 24-hour period.

Appendix A3

Surface Water Quality Data

Table A3.1 Mean daily water quality data collected from the bottom (11 m) of Mrs. T's Lake at station PZ-1 in 2018.

Day	August				September				October			
	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)
1	-	-	-	-	4.8	359.80	7.67	-0.31	6.1	332.40	8.17	10.44
2	-	-	-	-	4.8	360.10	7.68	-0.30	5.8	332.68	8.20	10.75
3	-	-	-	-	4.8	359.57	7.67	-0.30	5.4	332.97	8.22	10.94
4	-	-	-	-	4.8	360.21	7.69	-0.30	4.9	333.39	8.21	10.92
5	-	-	-	-	4.8	360.47	7.69	-0.30	4.8	333.37	8.24	11.14
6	-	-	-	-	4.8	359.85	7.69	-0.30	4.5	333.60	8.24	11.21
7	-	-	-	-	4.8	360.01	7.69	-0.30	4.2	333.88	8.25	11.35
8	-	-	-	-	4.8	359.18	7.68	-0.30	3.9	334.15	8.26	11.37
9	-	-	-	-	4.8	360.27	7.69	-0.29	3.9	334.43	8.26	11.39
10	-	-	-	-	4.8	360.23	7.69	-0.29	3.8	334.79	8.26	11.38
11	-	-	-	-	4.8	359.51	7.68	-0.29	3.9	336.15	8.21	10.95
12	-	-	-	-	4.8	360.18	7.69	-0.29	3.6	335.08	8.26	11.48
13	-	-	-	-	4.8	358.27	7.67	-0.29	3.3	335.26	8.30	11.84
14	-	-	-	-	4.9	354.33	7.63	-0.29	3.2	335.42	8.30	11.83
15	-	-	-	-	5.0	352.63	7.61	-0.28	3.2	335.62	8.31	11.92
16	-	-	-	-	5.1	351.52	7.60	-0.26	3.3	335.85	8.32	12.05
17	-	-	-	-	5.2	349.39	7.58	-0.23	3.3	335.88	8.31	11.97
18	-	-	-	-	5.4	346.35	7.55	-0.04	3.3	335.73	8.31	11.98
19	-	-	-	-	5.6	345.44	7.55	0.13	-	-	-	-
20	-	-	-	-	6.0	339.70	7.54	1.29	-	-	-	-
21	-	-	-	-	6.0	339.21	7.51	1.01	-	-	-	-
22	-	-	-	-	6.3	337.14	7.54	1.88	-	-	-	-
23	-	-	-	-	6.6	336.32	7.60	3.18	-	-	-	-
24	4.7	359.24	7.59	-0.28	7.1	333.64	7.82	6.61	-	-	-	-
25	4.7	360.46	7.62	-0.32	7.2	332.79	7.91	7.75	-	-	-	-
26	4.7	360.48	7.62	-0.32	7.3	331.92	8.02	8.86	-	-	-	-
27	4.7	360.05	7.62	-0.32	7.3	331.60	8.12	9.81	-	-	-	-
28	4.7	361.70	7.65	-0.32	6.9	331.85	8.12	9.93	-	-	-	-
29	4.7	361.88	7.66	-0.31	6.6	332.01	8.15	10.25	-	-	-	-
30	4.7	361.61	7.66	-0.31	6.3	332.19	8.16	10.37	-	-	-	-
31	4.7	361.74	7.67	-0.31	-	-	-	-	-	-	-	-
Minimum Daily	4.7	359.24	7.59	-0.32	4.8	331.60	7.51	-0.31	3.2	332.40	8.17	10.44
Mean	4.7	361.05	7.64	-0.31	5.6	348.52	7.73	2.20	4.1	334.48	8.26	11.38
Maximum Daily	4.7	362.30	7.69	-0.28	7.3	360.47	8.16	10.37	6.1	336.15	8.32	12.05

Table A3.2 Mean daily water quality data collected from the middle (11 m) of Mrs. T's Lake at station PZ-1 in 2018.

Day	August				September				October			
	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)
1	-	-	-	-	11.3	326.91	7.51	2.37	6.2	339.39	8.17	10.63
2	-	-	-	-	12.0	331.22	7.73	5.19	5.9	339.70	8.19	10.86
3	-	-	-	-	12.0	331.76	7.81	5.81	5.4	340.03	8.21	11.05
4	-	-	-	-	11.8	332.96	7.92	6.98	5.2	340.19	8.21	11.09
5	-	-	-	-	12.0	333.95	8.08	8.21	4.8	340.37	8.23	11.26
6	-	-	-	-	11.8	334.23	8.09	8.30	4.6	340.55	8.24	11.33
7	-	-	-	-	11.7	334.62	8.09	8.38	4.2	340.85	8.25	11.46
8	-	-	-	-	11.7	334.53	8.12	8.56	4.0	341.14	8.26	11.51
9	-	-	-	-	11.5	333.76	8.17	9.14	3.9	341.34	8.26	11.53
10	-	-	-	-	10.8	334.05	8.12	8.98	3.8	341.53	8.26	11.57
11	-	-	-	-	10.7	334.09	8.15	9.22	3.8	341.79	8.26	11.55
12	-	-	-	-	9.9	334.26	8.12	9.25	3.6	341.87	8.27	11.69
13	-	-	-	-	9.3	334.71	8.09	9.15	3.3	342.26	8.29	11.97
14	-	-	-	-	9.0	335.17	8.08	9.16	3.2	342.42	8.29	11.99
15	-	-	-	-	8.7	335.43	8.08	9.24	3.1	342.62	8.30	12.12
16	-	-	-	-	8.7	335.75	8.07	9.17	3.2	342.64	8.31	12.14
17	-	-	-	-	8.6	336.2	8.09	9.33	3.2	342.71	8.31	12.12
18	-	-	-	-	8.7	336.21	8.11	9.54	3.3	342.76	8.31	12.15
19	-	-	-	-	8.6	336.58	8.10	9.52	-	-	-	-
20	-	-	-	-	8.6	336.84	8.11	9.68	-	-	-	-
21	-	-	-	-	8.2	337.25	8.09	9.57	-	-	-	-
22	-	-	-	-	8.0	337.53	8.09	9.52	-	-	-	-
23	9.4	321.68		-0.23	7.9	337.72	8.10	9.63	-	-	-	-
24	9.3	321.03	7.30	-0.26	7.7	338.09	8.08	9.56	-	-	-	-
25	9.3	320.98	7.31	-0.26	7.6	338.35	8.08	9.54	-	-	-	-
26	9.3	321.23	7.31	-0.26	7.7	338.46	8.10	9.77	-	-	-	-
27	9.6	321.28	7.32	-0.24	7.3	338.70	8.11	9.93	-	-	-	-
28	9.9	321.45	7.32	-0.23	7.0	338.87	8.12	10.07	-	-	-	-
29	10.0	321.29	7.32	-0.25	6.7	339.10	8.15	10.36	-	-	-	-
30	10.1	322.38	7.36	0.28	6.4	339.25	8.16	10.50	-	-	-	-
31	11.1	325.20	7.45	1.63	-	-	-	-	-	-	-	-
Minimum Daily	9.30	320.98	7.30	-0.26	6.40	326.91	7.51	2.37	3.10	339.39	8.17	10.63
Mean	9.78	321.84	7.34	0.02	9.40	335.55	8.06	8.79	4.15	341.34	8.26	11.56
Maximum Daily	11.10	325.20	7.45	1.63	12.00	339.25	8.17	10.50	6.20	342.76	8.31	12.15

Table A3.3 Mean daily water quality data collected from the top (0.5 m) of Mrs. T's Lake at station PZ-1 in 2018.

Day	August				September				October			
	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)	Temp (°C)	Specific Conductivity (µS/cm)	Ph	Dissolved Oxygen (mg/L)
1	-	-	-	-	14.0	341.55	8.30	9.04	6.3	346.16	8.17	10.55
2	-	-	-	-	13.8	341.61	8.30	9.18	5.9	346.50	8.19	10.75
3	-	-	-	-	13.6	341.41	8.30	9.29	5.4	346.82	8.21	10.94
4	-	-	-	-	12.7	341.24	8.24	9.08	5.2	346.97	8.22	11.00
5	-	-	-	-	12.7	341.31	8.27	9.40	4.8	347.18	8.23	11.15
6	-	-	-	-	12.5	341.36	8.28	9.54	4.6	347.38	8.24	11.23
7	-	-	-	-	12.3	341.34	8.28	9.54	4.3	347.70	8.25	11.34
8	-	-	-	-	12.3	341.37	8.30	9.72	4.0	348.01	8.26	11.43
9	-	-	-	-	11.6	340.67	8.21	9.35	3.9	348.21	8.26	11.43
10	-	-	-	-	11.0	340.87	8.16	9.17	3.8	348.38	8.27	11.49
11	-	-	-	-	10.7	340.96	8.16	9.26	3.8	348.36	8.27	11.47
12	-	-	-	-	9.9	341.13	8.12	9.24	3.6	348.75	8.28	11.60
13	-	-	-	-	9.4	341.50	8.10	9.22	3.2	349.27	8.30	11.87
14	-	-	-	-	9.1	342.00	8.09	9.20	3.1	349.58	8.31	11.95
15	-	-	-	-	9.2	342.35	8.10	9.38	3.1	349.59	8.31	12.00
16	-	-	-	-	9.1	342.49	8.11	9.50	3.1	349.71	8.32	12.07
17	-	-	-	-	9.0	342.74	8.12	9.58	3.1	349.77	8.32	12.05
18	-	-	-	-	8.9	343.08	8.13	9.70	3.3	349.71	8.32	12.07
19	-	-	-	-	8.9	343.23	8.14	9.78	-	-	-	-
20	-	-	-	-	8.8	343.57	8.13	9.82	-	-	-	-
21	-	-	-	-	8.6	343.97	8.11	9.68	-	-	-	-
22	-	-	-	-	8.3	344.15	8.11	9.67	-	-	-	-
23	17.5	343.67	8.39	8.39	7.9	344.46	8.10	9.65	-	-	-	-
24	16.8	343.45	8.35	8.21	7.9	344.90	8.09	9.57	-	-	-	-
25	15.8	343.49	8.33	8.29	7.8	345.07	8.09	9.61	-	-	-	-
26	15.2	343.23	8.3	8.25	7.7	345.25	8.10	9.73	-	-	-	-
27	14.7	343.27	8.3	8.43	7.3	345.49	8.11	9.86	-	-	-	-
28	14.6	343.31	8.32	8.63	7.1	345.67	8.12	9.98	-	-	-	-
29	14.3	342.8	8.31	8.61	6.7	345.89	8.14	10.25	-	-	-	-
30	14.1	342.58	8.31	8.7	6.4	346.03	8.16	10.42	-	-	-	-
31	14	342.05	8.29	8.8	-	-	-	-	-	-	-	-
Minimum Daily	14.00	342.05	8.29	8.21	6.40	340.67	8.09	9.04	3.10	346.16	8.17	10.55
Mean	15.22	343.09	8.32	8.48	9.84	342.89	8.17	9.55	4.14	348.23	8.26	11.47
Maximum Daily	17.50	343.67	8.39	8.80	14.00	346.03	8.30	10.42	6.30	349.77	8.32	12.07

Table A3.4 In situ profiles of temperature, specific conductivity, pH, and dissolved oxygen measured at station PZ-1, Mrs. T's Lake, 2018.

Depth (m)	Temperature (°C)			Specific Conductivity (µS/cm)			Dissolved Oxygen (mg/L)			pH		
	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep	Jul	Aug	Sep
0.3	17.3	17.4	9.2	330.3	350.4	339.6	8.11	8.54	9.04	8.05	7.94	8.09
1.0	17.3	17.4	9.2	330.3	350.5	339.7	8.09	8.51	8.97	8.08	8.01	8.02
2.0	17.2	17.4	9.2	330.3	350.7	339.7	8.08	8.50	8.96	8.11	8.03	8.01
3.0	17.2	17.4	9.2	330.2	350.6	339.8	8.06	8.45	8.95	8.12	8.04	8.00
4.0	17.1	17.4	9.2	330.1	350.7	339.7	8.02	8.39	8.95	8.13	8.05	8.00
5.0	15.0	14.6	9.2	330.8	339.6	339.7	3.76	2.08	8.93	7.68	7.62	7.99
6.0	9.3	7.5	9.2	323.7	341.7	340.0	1.13	0.70	8.84	7.61	7.52	7.97
7.0	7.0	6.2	9.1	326.8	344.9	340.2	1.65	0.58	8.47	7.56	7.41	7.93
8.0	5.9	5.5	9.0	334.9	349.4	340.5	1.42	0.54	8.18	7.5	7.34	7.91
9.0	5.4	5.1	8.9	340.5	355.4	341.2	0.97	0.51	7.75	7.46	7.29	7.87
10.0	5.1	4.9	6.1	345.1	369.8	340.3	0.66	0.50	0.93	7.4	7.15	7.67
11.0	4.8	4.7	4.8	351.5	384.0	371.7	0.42	0.49	0.65	7.36	7.10	7.44
12.0	4.6	-	4.7	365.1	-	375.0	0.39	-	0.56	7.27	-	7.41

Values in blue indicate below acute GoA (2018) guideline of 5.0 mg/L (min).

Hatfield Consultants
ATTN: Chris Jaeggle/Andrew Aogorman
Suite A 300 Mackenzie BLVD
Fort McMurray AB T9H 4C4

Date Received: 24-JUL-18
Report Date: 24-AUG-18 16:09 (MT)
Version: FINAL

Client Phone: 604-330-2474

Certificate of Analysis

Lab Work Order #: L2134998
Project P.O. #: CNUL9184
Job Reference:
C of C Numbers:
Legal Site Desc:

Dana Brown, Chem. Tech. DIPL
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-1 BUOY TOP							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	1.61		0.10	ug/L	25-JUL-18	25-JUL-18	R4168135
GROUP 1 - RAMP							
Color, True							
Color, True	41.3		2.0	C.U.		25-JUL-18	R4140429
Ion Balance Calculation							
Ion Balance	90.8			%		15-AUG-18	
TDS (Calculated)	201			mg/L		15-AUG-18	
Hardness (as CaCO3)	152			mg/L		15-AUG-18	
Total Dissolved Solids							
Total Dissolved Solids	234		10	mg/L		31-JUL-18	R4152878
Total Suspended Solids							
Total Suspended Solids	4.6		3.0	mg/L		31-JUL-18	R4152825
pH, Conductivity and Alkalinity (T & P)							
pH	8.21		0.10	pH		04-AUG-18	R4159313
Conductivity (EC)	325		2.0	uS/cm		04-AUG-18	R4159313
Bicarbonate Alkalinity (as HCO3)	190		5.0	mg/L		04-AUG-18	R4159313
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313
Alkalinity, Total (as CaCO3)	156		2.0	mg/L		04-AUG-18	R4159313
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	7.98		0.50	mg/L		25-JUL-18	R4140058
Sulfate in Water by IC							
Sulfate (SO4)	31.4		0.30	mg/L		25-JUL-18	R4140058
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		01-AUG-18	R4152602
Nitrate in Water by IC							
Nitrate (as N)	0.052		0.020	mg/L		25-JUL-18	R4140058
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	0.052		0.022	mg/L		27-JUL-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		25-JUL-18	R4140058
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	16-AUG-18	17-AUG-18	R4175708
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0143		0.0010	mg/L		20-AUG-18	R4178596
Total P in Water by Colour							
Phosphorus (P)-Total	0.0128		0.0010	mg/L		20-AUG-18	R4178596
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		23-AUG-18	R4182123
Dissolved Metals							
Total Metals							
Miscellaneous Parameters							
Biochemical Oxygen Demand	2.5		2.0	mg/L		25-JUL-18	R4147072
Chlorine, Total	<0.10		0.10	mg/L		25-JUL-18	R4145624
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		25-JUL-18	R4139994
Dissolved Organic Carbon	16.6		0.50	mg/L		15-AUG-18	R4172341
Naphthenic Acids	0.29		0.10	mg/L	03-AUG-18	03-AUG-18	R4158897

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-1 BUOY TOP							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
Phenols (4AAP)	0.0018		0.0010	mg/L		01-AUG-18	R4153713
Boron (B)-Total	0.071	DLM	0.010	mg/L		15-AUG-18	R4169221
Mercury (Hg)-Total	0.00097		0.00050	ug/L		02-AUG-18	R4155671
Total Organic Carbon	16.6		0.50	mg/L		15-AUG-18	R4172270
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.037	DLM	0.015	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Total	0.0418	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Total	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Total	45.6	DLM	0.25	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Total	0.00056	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Iron (Fe)-Total	0.152	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Total	0.0103	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Total	12.6	DLM	0.025	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Total	0.0152	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Total	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Total	2.00	DLM	0.25	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Total	0.0016	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Total	3.36	DLM	0.50	mg/L		15-AUG-18	R4169221
Silver (Ag)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Total	13.0	DLM	0.25	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Total	0.130	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Total	8.2	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Total	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Total	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Total	0.000209	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Total	<0.015	DLM	0.015	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Total	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-AUG-18	R4152830
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-AUG-18	02-AUG-18	R4156372
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Boron (B)-Dissolved	0.073		0.010	mg/L		15-AUG-18	R4169221
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Aluminum (Al)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-1 BUOY TOP							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Antimony (Sb)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Dissolved	0.0392	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Dissolved	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Dissolved	41.4	DLM	0.50	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Iron (Fe)-Dissolved	<0.050	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Dissolved	0.0099	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Dissolved	11.9	DLM	0.10	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Dissolved	0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Dissolved	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Dissolved	1.92	DLM	0.50	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Dissolved	0.0013	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Dissolved	3.36	DLM	0.25	mg/L		15-AUG-18	R4169221
Silver (Ag)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Dissolved	12.3	DLM	1.0	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Dissolved	0.124	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Dissolved	7.6	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Dissolved	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Dissolved	0.000188	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Dissolved	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
L2134998-2 BUOY BOTTOM							
Sampled By: HK,AO on 24-JUL-18 @ 13:00							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	0.34		0.10	ug/L	25-JUL-18	25-JUL-18	R4168135
GROUP 1 - RAMP							
Color, True							
Color, True	50.4		2.0	C.U.		25-JUL-18	R4140429
Ion Balance Calculation							
Ion Balance	100			%		15-AUG-18	
TDS (Calculated)	192			mg/L		15-AUG-18	
Hardness (as CaCO3)	155			mg/L		15-AUG-18	
Total Dissolved Solids							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-2 BUOY BOTTOM							
Sampled By: HK,AO on 24-JUL-18 @ 13:00							
Matrix: SW							
Total Dissolved Solids							
Total Dissolved Solids	244		10	mg/L		31-JUL-18	R4152878
Total Suspended Solids							
Total Suspended Solids	4.5		3.0	mg/L		31-JUL-18	R4152825
pH, Conductivity and Alkalinity (T & P)							
pH	8.00		0.10	pH		04-AUG-18	R4159313
Conductivity (EC)	335		2.0	uS/cm		04-AUG-18	R4159313
Bicarbonate Alkalinity (as HCO3)	193		5.0	mg/L		04-AUG-18	R4159313
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313
Alkalinity, Total (as CaCO3)	158		2.0	mg/L		04-AUG-18	R4159313
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	5.50		0.50	mg/L		25-JUL-18	R4140058
Sulfate in Water by IC							
Sulfate (SO4)	20.5		0.30	mg/L		25-JUL-18	R4140058
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	0.183		0.050	mg/L		01-AUG-18	R4152602
Nitrate in Water by IC							
Nitrate (as N)	0.148		0.020	mg/L		25-JUL-18	R4140058
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	0.167		0.022	mg/L		27-JUL-18	
Nitrite in Water by IC							
Nitrite (as N)	0.020		0.010	mg/L		25-JUL-18	R4140058
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	16-AUG-18	17-AUG-18	R4175708
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0083		0.0010	mg/L		20-AUG-18	R4178596
Total P in Water by Colour							
Phosphorus (P)-Total	0.0296		0.0010	mg/L		20-AUG-18	R4178596
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		23-AUG-18	R4182123
Dissolved Metals							
Total Metals							
Miscellaneous Parameters							
Biochemical Oxygen Demand	2.1		2.0	mg/L		25-JUL-18	R4147072
Chlorine, Total	<0.10		0.10	mg/L		25-JUL-18	R4145624
Orthophosphate-Dissolved (as P)	0.010		0.010	mg/L		25-JUL-18	R4139994
Dissolved Organic Carbon	15.8		0.50	mg/L		15-AUG-18	R4172341
Naphthenic Acids	0.37		0.10	mg/L	03-AUG-18	03-AUG-18	R4158897
Phenols (4AAP)	0.0016		0.0010	mg/L		01-AUG-18	R4153713
Boron (B)-Total	0.081	DLM	0.010	mg/L		15-AUG-18	R4169221
Mercury (Hg)-Total	0.00088		0.00050	ug/L		01-AUG-18	R4152920
Total Organic Carbon	15.7		0.50	mg/L		15-AUG-18	R4172270
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.024	DLM	0.015	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Total	0.0419	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-2 BUOY BOTTOM							
Sampled By: HK,AO on 24-JUL-18 @ 13:00							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Bismuth (Bi)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Total	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Total	46.7	DLM	0.25	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Total	0.00067	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Iron (Fe)-Total	0.418	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Total	0.0105	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Total	13.0	DLM	0.025	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Total	0.321	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Total	0.00044	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Total	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Total	2.20	DLM	0.25	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Total	0.0017	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Total	3.92	DLM	0.50	mg/L		15-AUG-18	R4169221
Silver (Ag)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Total	14.0	DLM	0.25	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Total	0.128	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Total	8.3	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Total	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Total	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Total	0.000267	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Total	<0.015	DLM	0.015	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Total	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-AUG-18	R4152830
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-AUG-18	02-AUG-18	R4156372
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Boron (B)-Dissolved	0.082		0.010	mg/L		15-AUG-18	R4169221
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Aluminum (Al)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Dissolved	0.0383	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Dissolved	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Dissolved	42.2	DLM	0.50	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-2 BUOY BOTTOM							
Sampled By: HK,AO on 24-JUL-18 @ 13:00							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Copper (Cu)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Iron (Fe)-Dissolved	0.127	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Dissolved	0.0098	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Dissolved	12.0	DLM	0.10	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Dissolved	0.121	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Dissolved	0.00037	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Dissolved	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Dissolved	2.08	DLM	0.50	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Dissolved	0.0017	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Dissolved	3.78	DLM	0.25	mg/L		15-AUG-18	R4169221
Silver (Ag)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Dissolved	13.7	DLM	1.0	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Dissolved	0.120	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Dissolved	7.7	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Dissolved	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Dissolved	0.000240	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Dissolved	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
L2134998-3 OUTLET							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	1.88		0.10	ug/L	25-JUL-18	25-JUL-18	R4168135
GROUP 1 - RAMP							
Color, True							
Color, True	43.9		2.0	C.U.		25-JUL-18	R4140429
Ion Balance Calculation							
Ion Balance	98.9			%		15-AUG-18	
TDS (Calculated)	182			mg/L		15-AUG-18	
Hardness (as CaCO3)	149			mg/L		15-AUG-18	
Total Dissolved Solids							
Total Dissolved Solids	230		10	mg/L		31-JUL-18	R4152878
Total Suspended Solids							
Total Suspended Solids	6.0		3.0	mg/L		31-JUL-18	R4152825
pH, Conductivity and Alkalinity (T & P)							
pH	8.22		0.10	pH		04-AUG-18	R4159313
Conductivity (EC)	319		2.0	uS/cm		04-AUG-18	R4159313
Bicarbonate Alkalinity (as HCO3)	188		5.0	mg/L		04-AUG-18	R4159313
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-3 OUTLET							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
pH, Conductivity and Alkalinity (T & P)							
Alkalinity, Total (as CaCO3)	154		2.0	mg/L		04-AUG-18	R4159313
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	4.36		0.50	mg/L		25-JUL-18	R4140058
Sulfate in Water by IC							
Sulfate (SO4)	19.3		0.30	mg/L		25-JUL-18	R4140058
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		01-AUG-18	R4152602
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		25-JUL-18	R4140058
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		27-JUL-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		25-JUL-18	R4140058
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	16-AUG-18	17-AUG-18	R4175708
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0062		0.0010	mg/L		20-AUG-18	R4178596
Total P in Water by Colour							
Phosphorus (P)-Total	0.0139		0.0010	mg/L		20-AUG-18	R4178596
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		23-AUG-18	R4182123
Dissolved Metals							
Total Metals							
Miscellaneous Parameters							
Biochemical Oxygen Demand	<2.0		2.0	mg/L		25-JUL-18	R4147072
Chlorine, Total	<0.10		0.10	mg/L		25-JUL-18	R4145624
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		25-JUL-18	R4139994
Dissolved Organic Carbon	17.2		0.50	mg/L		15-AUG-18	R4172341
Naphthenic Acids	0.33		0.10	mg/L	03-AUG-18	03-AUG-18	R4158897
Phenols (4AAP)	0.0017		0.0010	mg/L		01-AUG-18	R4153713
Boron (B)-Total	0.071	DLM	0.010	mg/L		15-AUG-18	R4169221
Mercury (Hg)-Total	0.00101		0.00050	ug/L		01-AUG-18	R4152920
Total Organic Carbon	16.7		0.50	mg/L		15-AUG-18	R4172270
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.083	DLM	0.015	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Total	0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Total	0.0429	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Total	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Total	46.2	DLM	0.25	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Total	0.00065	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Iron (Fe)-Total	0.268	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-3 OUTLET							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Lithium (Li)-Total	0.0116	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Total	12.8	DLM	0.025	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Total	0.0136	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Total	0.00028	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Total	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Total	2.01	DLM	0.25	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Total	0.0016	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Total	3.53	DLM	0.50	mg/L		15-AUG-18	R4169221
Silver (Ag)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Total	13.1	DLM	0.25	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Total	0.140	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Total	8.1	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Total	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Total	0.0017	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Total	0.000214	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Total	<0.015	DLM	0.015	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Total	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-AUG-18	R4152830
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-AUG-18	02-AUG-18	R4156372
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Boron (B)-Dissolved	0.071		0.010	mg/L		15-AUG-18	R4169221
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Aluminum (Al)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Dissolved	0.0402	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Dissolved	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Dissolved	40.2	DLM	0.50	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Iron (Fe)-Dissolved	<0.050	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Dissolved	0.0105	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Dissolved	11.8	DLM	0.10	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Dissolved	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-3 OUTLET							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Potassium (K)-Dissolved	1.89	DLM	0.50	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Dissolved	0.0013	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Dissolved	3.30	DLM	0.25	mg/L		15-AUG-18	R4169221
Silver (Ag)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Dissolved	12.4	DLM	1.0	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Dissolved	0.122	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Dissolved	7.5	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Dissolved	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Dissolved	0.000202	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Dissolved	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
L2134998-4 DUPLICATE							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	1.96		0.10	ug/L	25-JUL-18	25-JUL-18	R4168135
GROUP 1 - RAMP							
Color, True							
Color, True	41.1		2.0	C.U.		25-JUL-18	R4140429
Ion Balance Calculation							
Ion Balance	99.2			%		15-AUG-18	
TDS (Calculated)	182			mg/L		15-AUG-18	
Hardness (as CaCO3)	149			mg/L		15-AUG-18	
Total Dissolved Solids							
Total Dissolved Solids	223		10	mg/L		31-JUL-18	R4152878
Total Suspended Solids							
Total Suspended Solids	6.6		3.0	mg/L		31-JUL-18	R4152825
pH, Conductivity and Alkalinity (T & P)							
pH	8.20		0.10	pH		04-AUG-18	R4159313
Conductivity (EC)	319		2.0	uS/cm		04-AUG-18	R4159313
Bicarbonate Alkalinity (as HCO3)	187		5.0	mg/L		04-AUG-18	R4159313
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313
Alkalinity, Total (as CaCO3)	153		2.0	mg/L		04-AUG-18	R4159313
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	4.39		0.50	mg/L		25-JUL-18	R4140058
Sulfate in Water by IC							
Sulfate (SO4)	19.4		0.30	mg/L		25-JUL-18	R4140058
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		01-AUG-18	R4152602
Nitrate in Water by IC							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-4 DUPLICATE							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		25-JUL-18	R4140058
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		27-JUL-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		25-JUL-18	R4140058
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	16-AUG-18	17-AUG-18	R4175708
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0355		0.0010	mg/L		20-AUG-18	R4178596
Total P in Water by Colour							
Phosphorus (P)-Total	0.0155		0.0010	mg/L		20-AUG-18	R4178596
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		23-AUG-18	R4182123
Dissolved Metals							
Total Metals							
Miscellaneous Parameters							
Biochemical Oxygen Demand	<2.0		2.0	mg/L		25-JUL-18	R4147072
Chlorine, Total	<0.10		0.10	mg/L		25-JUL-18	R4145624
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		25-JUL-18	R4139994
Dissolved Organic Carbon	16.8		0.50	mg/L		15-AUG-18	R4172341
Naphthenic Acids	0.33		0.10	mg/L	03-AUG-18	03-AUG-18	R4158897
Phenols (4AAP)	0.0014		0.0010	mg/L		01-AUG-18	R4153713
Boron (B)-Total	0.073	DLM	0.010	mg/L		15-AUG-18	R4169221
Mercury (Hg)-Total	0.00100		0.00050	ug/L		01-AUG-18	R4152920
Total Organic Carbon	16.6		0.50	mg/L		15-AUG-18	R4172270
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.073	DLM	0.015	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Total	0.0432	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Total	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Total	44.8	DLM	0.25	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Total	0.00073	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Iron (Fe)-Total	0.246	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Total	0.0114	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Total	13.2	DLM	0.025	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Total	0.0133	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Total	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Total	2.03	DLM	0.25	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Total	0.0015	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Total	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Total	3.55	DLM	0.50	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-4 DUPLICATE							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Silver (Ag)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Total	13.4	DLM	0.25	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Total	0.130	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Total	7.8	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Total	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Total	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Thorium (Th)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Total	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Total	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Total	0.000204	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Total	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Total	<0.015	DLM	0.015	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Total	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-AUG-18	R4152830
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-AUG-18	02-AUG-18	R4156372
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Boron (B)-Dissolved	0.072		0.010	mg/L		15-AUG-18	R4169221
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Aluminum (Al)-Dissolved	0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Arsenic (As)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Barium (Ba)-Dissolved	0.0391	DLM	0.00050	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Dissolved	<0.000025	DLM	0.000025	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Dissolved	39.9	DLM	0.50	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Copper (Cu)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Iron (Fe)-Dissolved	<0.050	DLM	0.050	mg/L		15-AUG-18	R4169221
Lead (Pb)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Lithium (Li)-Dissolved	0.0103	DLM	0.0050	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Dissolved	11.9	DLM	0.10	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Dissolved	<0.25	DLM	0.25	mg/L		15-AUG-18	R4169221
Potassium (K)-Dissolved	1.89	DLM	0.50	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Dissolved	0.0015	DLM	0.0010	mg/L		15-AUG-18	R4169221
Selenium (Se)-Dissolved	<0.00025	DLM	0.00025	mg/L		15-AUG-18	R4169221
Silicon (Si)-Dissolved	3.32	DLM	0.25	mg/L		15-AUG-18	R4169221
Silver (Ag)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221
Sodium (Na)-Dissolved	12.5	DLM	1.0	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Dissolved	0.124	DLM	0.0010	mg/L		15-AUG-18	R4169221
Sulfur (S)-Dissolved	7.7	DLM	2.5	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Dissolved	<0.0010	DLM	0.0010	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Dissolved	<0.000050	DLM	0.000050	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-4 DUPLICATE							
Sampled By: HK,AO on 24-JUL-18 @ 14:40							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Thorium (Th)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Tin (Sn)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Dissolved	<0.0015	DLM	0.0015	mg/L		15-AUG-18	R4169221
Tungsten (W)-Dissolved	<0.00050	DLM	0.00050	mg/L		15-AUG-18	R4169221
Uranium (U)-Dissolved	0.000196	DLM	0.000050	mg/L		15-AUG-18	R4169221
Vanadium (V)-Dissolved	<0.0025	DLM	0.0025	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Dissolved	<0.0050	DLM	0.0050	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Dissolved	<0.00030	DLM	0.00030	mg/L		15-AUG-18	R4169221
L2134998-5 TB (TRIP BLANK)							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
GROUP 1 - RAMP							
Color, True							
Color, True	<2.0		2.0	C.U.		25-JUL-18	R4140429
Ion Balance Calculation							
Ion Balance	Low TDS			%		15-AUG-18	
TDS (Calculated)	<1.0			mg/L		15-AUG-18	
Hardness (as CaCO3)	<1.0			mg/L		15-AUG-18	
Total Dissolved Solids							
Total Dissolved Solids	<10		10	mg/L		31-JUL-18	R4152878
Total Suspended Solids							
Total Suspended Solids	<3.0		3.0	mg/L		31-JUL-18	R4152825
pH, Conductivity and Alkalinity (T & P)							
pH	5.89		0.10	pH		04-AUG-18	R4159313
Conductivity (EC)	<2.0		2.0	uS/cm		04-AUG-18	R4159313
Bicarbonate Alkalinity (as HCO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		04-AUG-18	R4159313
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313
Alkalinity, Total (as CaCO3)	<2.0		2.0	mg/L		04-AUG-18	R4159313
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	<0.50		0.50	mg/L		25-JUL-18	R4140058
Sulfate in Water by IC							
Sulfate (SO4)	<0.30		0.30	mg/L		25-JUL-18	R4140058
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		31-JUL-18	R4151740
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		25-JUL-18	R4140058
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		27-JUL-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		25-JUL-18	R4140058
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	15-AUG-18	16-AUG-18	R4173328
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	<0.0010		0.0010	mg/L		20-AUG-18	R4178596
Total P in Water by Colour							
Phosphorus (P)-Total	<0.0010		0.0010	mg/L		20-AUG-18	R4178596
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-5 TB (TRIP BLANK)							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		23-AUG-18	R4182123
Dissolved Metals							
Total Metals							
Miscellaneous Parameters							
Biochemical Oxygen Demand	<2.0		2.0	mg/L		25-JUL-18	R4147072
Chlorine, Total	<0.10		0.10	mg/L		25-JUL-18	R4145624
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		25-JUL-18	R4139994
Dissolved Organic Carbon	<0.50		0.50	mg/L		15-AUG-18	R4172341
Naphthenic Acids	0.33		0.10	mg/L	03-AUG-18	03-AUG-18	R4158897
Phenols (4AAP)	<0.0010		0.0010	mg/L		03-AUG-18	R4158089
Boron (B)-Total	0.0079	RRV	0.0020	mg/L		15-AUG-18	R4169221
Total Organic Carbon	<0.50		0.50	mg/L		15-AUG-18	R4172270
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	<0.0030		0.0030	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Arsenic (As)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Barium (Ba)-Total	0.00023	RRV	0.00010	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Total	0.0000066	RRV	0.0000050	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Total	<0.050		0.050	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Copper (Cu)-Total	<0.00050		0.00050	mg/L		15-AUG-18	R4169221
Iron (Fe)-Total	<0.010		0.010	mg/L		15-AUG-18	R4169221
Lead (Pb)-Total	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Lithium (Li)-Total	<0.0010		0.0010	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Total	<0.0050		0.0050	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Total	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Total	<0.00050		0.00050	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Total	<0.050		0.050	mg/L		15-AUG-18	R4169221
Potassium (K)-Total	<0.050		0.050	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Total	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Selenium (Se)-Total	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Silicon (Si)-Total	<0.10		0.10	mg/L		15-AUG-18	R4169221
Silver (Ag)-Total	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Sodium (Na)-Total	<0.050		0.050	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Total	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Sulfur (S)-Total	<0.50		0.50	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Thorium (Th)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Tin (Sn)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		15-AUG-18	R4169221
Tungsten (W)-Total	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Uranium (U)-Total	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Vanadium (V)-Total	<0.00050		0.00050	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Total	<0.000060		0.000060	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2134998-5 TB (TRIP BLANK)							
Sampled By: HK,AO on 24-JUL-18 @ 12:30							
Matrix: SW							
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Boron (B)-Dissolved	0.0093	RRV	0.0020	mg/L		15-AUG-18	R4169221
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	FIELD					14-AUG-18	R4169219
Aluminum (Al)-Dissolved	<0.0010		0.0010	mg/L		15-AUG-18	R4169221
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Arsenic (As)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Barium (Ba)-Dissolved	0.00022		0.00010	mg/L		15-AUG-18	R4169221
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		15-AUG-18	R4169221
Calcium (Ca)-Dissolved	<0.50		0.50	mg/L		15-AUG-18	R4169221
Cesium (Cs)-Dissolved	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Copper (Cu)-Dissolved	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		15-AUG-18	R4169221
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Lithium (Li)-Dissolved	<0.0010		0.0010	mg/L		15-AUG-18	R4169221
Magnesium (Mg)-Dissolved	<0.10		0.10	mg/L		15-AUG-18	R4169221
Manganese (Mn)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Molybdenum (Mo)-Dissolved	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Nickel (Ni)-Dissolved	<0.00050		0.00050	mg/L		15-AUG-18	R4169221
Phosphorus (P)-Dissolved	<0.050		0.050	mg/L		15-AUG-18	R4169221
Potassium (K)-Dissolved	<0.50		0.50	mg/L		15-AUG-18	R4169221
Rubidium (Rb)-Dissolved	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Selenium (Se)-Dissolved	<0.000050		0.000050	mg/L		15-AUG-18	R4169221
Silicon (Si)-Dissolved	<0.050		0.050	mg/L		15-AUG-18	R4169221
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Sodium (Na)-Dissolved	<1.0		1.0	mg/L		15-AUG-18	R4169221
Strontium (Sr)-Dissolved	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Sulfur (S)-Dissolved	<0.50		0.50	mg/L		15-AUG-18	R4169221
Tellurium (Te)-Dissolved	<0.00020		0.00020	mg/L		15-AUG-18	R4169221
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Thorium (Th)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		15-AUG-18	R4169221
Tungsten (W)-Dissolved	<0.00010		0.00010	mg/L		15-AUG-18	R4169221
Uranium (U)-Dissolved	<0.000010		0.000010	mg/L		15-AUG-18	R4169221
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		15-AUG-18	R4169221
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		15-AUG-18	R4169221
Zirconium (Zr)-Dissolved	<0.00030		0.00030	mg/L		15-AUG-18	R4169221

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects (e.g. chemical interference, colour, turbidity).
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
B-D-L-CCMS-CL	Water	Dissolved Boron by CRC CCMS	APHA 3030B/6020A (mod)

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procudure involves filtration (APHA 3030B&E), then instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

B-T-L-CCMS-CL	Water	Total B (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

BOD-ED	Water	Biochemical Oxygen Demand (BOD)	APHA 5210 B-5 day Incub.-O2 electrode

Samples are diluted and seeded and then incubated in airtight bottles at 20 C for 5 days. Dissolved oxygen is measured initially and after incubation, and results are computed from the difference between initial and final DO.

C-DOC-HTC-WP	Water	Dissolved Organic Carbon by Combustion	APHA 5310 B-WP

Filtered (0.45 um) sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

C-TOC-HTC-WP	Water	Total Organic Carbon by Combustion	APHA 5310 B-WP

Sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

CHL/A-ACET-FLUORO-WP	Water	Chlorophyll a by fluorometry	EPA 445.0 ACET

This analysis is done using procedures modified from EPA method 445.0. Chlorophyll a is determined by a 90 % acetone extraction followed with analysis by fluorometry using the non-acidification procedure. This method is not subject to interferences from chlorophyll b.

CL-IC-N-ED	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CL2-TOT-ED	Water	Chlorine, Total	APHA 4500 Cl G-Colorimetry

Chlorine (residual), as free or total, is analyzed using the DPD colourimetric method. The recommended hold time for these tests is 15 minutes; field testing is recommended for best results. Chlorine can be rapidly consumed by organic matter, if present, and dissipates rapidly into headspace.

COL-TRU-ED	Water	Color, True	APHA 2120

True Colour is measured using a colorimeter by comparison to platinum-cobalt standards using the single wavelength method (450 - 465 nm) after filtration of sample through a 0.45 um filter. Colour measurements can be highly pH dependent, and apply to the pH of the sample as received (at time of testing), without pH adjustment. Concurrent measurement of sample pH is recommended.

HG-D-U-CVAF-VA	Water	Diss. Mercury in Water by CVAFS (Ultra)	APHA 3030 B / EPA 1631 REV. E

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure may involve preliminary sample treatment by filtration (APHA 3030B) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

HG-T-U-CVAF-VA	Water	Total Mercury in Water by CVAFS (Ultra)	EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

HOG-IR-ED	Water	Hydrocarbons,Rec. (I.R.)	APHA 5520 C-Tetra Cl Ext Infrared

A water sample is acidified and then liquid-liquid extracted using tetrachloroethylene solvent, followed by filtration of the decanted solvent into a volumetric flask. The extract is treated with silica gel to remove polar, naturally-occurring hydrocarbons, to yield mineral oil and grease. Finally, the extract is brought to a discrete final volume and analysed by infrared spectrophotometry. The absorbance of the carbon-hydrogen bond in the infrared is used to measure oil and grease. Spectra are collected in transmission mode using a glass cuvette.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
IONBALANCE-ED	Water	Ion Balance Calculation	APHA 1030E
MET-D-CCMS-CL	Water	Dissolved Metals in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

ALS Test Code	Matrix	Test Description	Method Reference**
MET-T-CCMS-CL	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

ALS Test Code	Matrix	Test Description	Method Reference**
NAPHTHENIC ACID-L-FM	Water	Naphthenic Acids by FTIR (Low Level)	Naphthenic Acids by FTIR,Syncrude,1994

Dissolved naphthenic acids are solvent extracted from acidified aqueous samples using Dichloromethane prior to quantitation by Fourier Transform Infra-Red spectroscopy. Note that FTIR is not uniquely selective to naphthenic acids. If present, other carboxylic acids (e.g. humic acids, fulvic acids) may also be detected by this method.

ALS Test Code	Matrix	Test Description	Method Reference**
NH3-COL-ED	Water	Ammonia in Water by Colour	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out using procedures adapted from APHA Method 4500 NH3 "NITROGEN (AMMONIA)". Ammonia is determined using the automated phenate colourimetric method.

ALS Test Code	Matrix	Test Description	Method Reference**
NO2+NO3-CALC-ED	Water	Nitrate+Nitrite	CALCULATION
NO2-IC-N-ED	Water	Nitrite in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
NO3-IC-N-ED	Water	Nitrate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
P-T-L-COL-ED	Water	Total P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

ALS Test Code	Matrix	Test Description	Method Reference**
P-TD-L-COL-ED	Water	Total Dissolved P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorous is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.

ALS Test Code	Matrix	Test Description	Method Reference**
PH/EC/ALKS-ED	Water	pH, Conductivity and Alkalinity (T & P)	APHA 4500-H, 2510, 2320

All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

ALS Test Code	Matrix	Test Description	Method Reference**
PHENOLS-4AAP-WT	Water	Phenol (4AAP)	EPA 9066

An automated method is used to distill the sample. The distillate is then buffered to pH 9.4 which reacts with 4AAP and potassium ferricyanide to form a red complex which is measured colorimetrically.

ALS Test Code	Matrix	Test Description	Method Reference**
PO4-DO-COL-ED	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

ALS Test Code	Matrix	Test Description	Method Reference**
SO4-IC-N-ED	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

ALS Test Code	Matrix	Test Description	Method Reference**
SOLIDS-TDS-ED	Water	Total Dissolved Solids	APHA 2540 C

Gravimetric determination of solids in waters by filtration and evaporating filtrate to dryness at 180 degrees Celsius.

ALS Test Code	Matrix	Test Description	Method Reference**
SOLIDS-TOTSUS-ED	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

Gravimetric determination of solids in waters by filtration and drying filter at 104 degrees Celsius.

ALS Test Code	Matrix	Test Description	Method Reference**
TKN-CFA-ED	Water	TKN in Water by Colour	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg "Nitrogen (Organic)". Total Kjeldahl Nitrogen is determined by sample digestion at 380 celcius with analysis using an automated colourimetric finish.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

Laboratory Definition Code	Laboratory Location
FM	ALS ENVIRONMENTAL - FORT MCMURRAY, ALBERTA, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Client: Hatfield Consultants
Suite A 300 Mackenzie BLVD
Fort McMurray AB T9H 4C4
Contact: Chris Jaeggle/Andrew Aogorman

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
B-D-L-CCMS-CL	Water							
Batch R4169221								
WG2849455-12 LCS		**TMRM**						
Boron (B)-Dissolved			116.0		%		80-120	15-AUG-18
WG2849455-4 LCS		**TMRM**						
Boron (B)-Dissolved			96.5		%		80-120	15-AUG-18
WG2849455-9 LCS		**TMRM**						
Boron (B)-Dissolved			98.3		%		80-120	15-AUG-18
WG2849455-11 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	15-AUG-18
WG2849455-3 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	15-AUG-18
WG2849455-8 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	15-AUG-18
B-T-L-CCMS-CL	Water							
Batch R4159507								
WG2841741-1 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	04-AUG-18
Batch R4159880								
WG2841741-5 LCS		**TMRM**						
Boron (B)-Total			101.5		%		80-120	06-AUG-18
WG2841741-4 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	06-AUG-18
Batch R4160413								
WG2841741-8 LCS		**TMRM**						
Boron (B)-Total			99.1		%		80-120	08-AUG-18
WG2841741-7 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	08-AUG-18
Batch R4169221								
WG2841741-3 DUP		**L2134998-1**						
Boron (B)-Total		0.071	0.071		mg/L	0.4	20	15-AUG-18
BOD-ED	Water							
Batch R4147072								
WG2832038-2 LCS								
Biochemical Oxygen Demand			101.3		%		85-115	25-JUL-18
WG2832038-4 MB								
Biochemical Oxygen Demand			<2.0		mg/L		2	25-JUL-18
WG2832038-3 RB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BOD-ED	Water							
Batch R4147072								
WG2832038-3 RB								
Biochemical Oxygen Demand			<2.0		mg/L			25-JUL-18
C-DOC-HTC-WP	Water							
Batch R4172341								
WG2851176-6 LCS								
Dissolved Organic Carbon			97.9		%		80-120	15-AUG-18
WG2851176-5 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	15-AUG-18
C-TOC-HTC-WP	Water							
Batch R4172270								
WG2851218-6 LCS								
Total Organic Carbon			97.9		%		80-120	15-AUG-18
WG2851218-5 MB								
Total Organic Carbon			<0.50		mg/L		0.5	15-AUG-18
CHL/A-ACET-FLUORO-WP	Water							
Batch R4168135								
WG2848054-4 DUP		**L2134998-1**						
Chlorophyll a		1.61	1.83		ug/L	13	35	25-JUL-18
WG2848054-7 LCS								
Chlorophyll a			109.1		%		80-120	13-AUG-18
WG2848054-1 MB								
Chlorophyll a			<0.10		ug/L		0.1	25-JUL-18
WG2848054-2 MB								
Chlorophyll a			<0.10		ug/L		0.1	30-JUL-18
WG2848054-3 MB								
Chlorophyll a			<0.10		ug/L		0.1	31-JUL-18
CL-IC-N-ED	Water							
Batch R4140058								
WG2831434-11 LCS								
Chloride (Cl)			101.7		%		90-110	25-JUL-18
WG2831434-13 LCS								
Chloride (Cl)			101.7		%		90-110	25-JUL-18
WG2831434-15 LCS								
Chloride (Cl)			101.8		%		90-110	25-JUL-18
WG2831434-17 LCS								
Chloride (Cl)			101.8		%		90-110	25-JUL-18
WG2831434-2 LCS								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-IC-N-ED	Water							
Batch R4140058								
WG2831434-2 LCS								
Chloride (Cl)			100.8		%		90-110	25-JUL-18
WG2831434-1 MB								
Chloride (Cl)			<0.50		mg/L		0.5	25-JUL-18
WG2831434-12 MB								
Chloride (Cl)			<0.50		mg/L		0.5	25-JUL-18
WG2831434-14 MB								
Chloride (Cl)			<0.50		mg/L		0.5	25-JUL-18
WG2831434-16 MB								
Chloride (Cl)			<0.50		mg/L		0.5	25-JUL-18
WG2831434-18 MB								
Chloride (Cl)			<0.50		mg/L		0.5	25-JUL-18
CL2-TOT-ED	Water							
Batch R4145624								
WG2831913-3 DUP		**L2134998-1**						
Chlorine, Total		<0.10	<0.10	RPD-NA	mg/L	N/A	15	25-JUL-18
WG2831913-2 LCS								
Chlorine, Total			98.0		%		75-125	25-JUL-18
WG2831913-1 MB								
Chlorine, Total			<0.10		mg/L		0.1	25-JUL-18
COL-TRU-ED	Water							
Batch R4140429								
WG2832318-3 DUP		**L2134998-4**						
Color, True		41.1	43.0		C.U.	4.6	20	25-JUL-18
WG2832318-2 LCS								
Color, True			96.8		%		85-115	25-JUL-18
WG2832318-1 MB								
Color, True			<2.0		C.U.		2	25-JUL-18
HG-D-U-CVAF-VA	Water							
Batch R4156372								
WG2838953-3 DUP		**L2134998-1**						
Mercury (Hg)-Dissolved		<0.00050	<0.00050	RPD-NA	ug/L	N/A	20	02-AUG-18
WG2838953-2 LCS								
Mercury (Hg)-Dissolved			107.7		%		80-120	02-AUG-18
WG2838953-1 MB		**LF**						
Mercury (Hg)-Dissolved			<0.00050		ug/L		0.0005	02-AUG-18
HG-T-U-CVAF-VA	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-T-U-CVAF-VA	Water							
Batch R4152920								
WG2838982-2 LCS								
Mercury (Hg)-Total			117.2		%		80-120	01-AUG-18
WG2838982-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	01-AUG-18
WG2838982-4 MS		**L2134998-3**						
Mercury (Hg)-Total			86.0		%		70-130	01-AUG-18
Batch R4155671								
WG2840092-2 LCS								
Mercury (Hg)-Total			107.4		%		80-120	02-AUG-18
WG2840092-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	02-AUG-18
HOG-IR-ED	Water							
Batch R4182123								
WG2857361-2 LCS								
Hydrocarbons, Recoverable (I.R.)			90.8		%		70-130	23-AUG-18
WG2857361-1 MB								
Hydrocarbons, Recoverable (I.R.)			<1.0		mg/L		1	23-AUG-18
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-12 LCS		**TMRM**						
Aluminum (Al)-Dissolved			100.2		%		80-120	15-AUG-18
Antimony (Sb)-Dissolved			111.1		%		80-120	15-AUG-18
Arsenic (As)-Dissolved			97.8		%		80-120	15-AUG-18
Barium (Ba)-Dissolved			101.4		%		80-120	15-AUG-18
Beryllium (Be)-Dissolved			108.7		%		80-120	15-AUG-18
Bismuth (Bi)-Dissolved			103.3		%		80-120	15-AUG-18
Cadmium (Cd)-Dissolved			98.4		%		80-120	15-AUG-18
Calcium (Ca)-Dissolved			100.2		%		80-120	15-AUG-18
Cesium (Cs)-Dissolved			96.2		%		80-120	15-AUG-18
Chromium (Cr)-Dissolved			99.4		%		80-120	15-AUG-18
Cobalt (Co)-Dissolved			98.3		%		80-120	15-AUG-18
Copper (Cu)-Dissolved			98.9		%		80-120	15-AUG-18
Iron (Fe)-Dissolved			112.2		%		80-120	15-AUG-18
Lead (Pb)-Dissolved			98.5		%		80-120	15-AUG-18
Lithium (Li)-Dissolved			106.4		%		80-120	15-AUG-18
Magnesium (Mg)-Dissolved			104.1		%		80-120	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-12 LCS		**TMRM**						
Manganese (Mn)-Dissolved			99.96		%		80-120	15-AUG-18
Molybdenum (Mo)-Dissolved			104.8		%		80-120	15-AUG-18
Nickel (Ni)-Dissolved			98.5		%		80-120	15-AUG-18
Phosphorus (P)-Dissolved			107.2		%		70-130	15-AUG-18
Potassium (K)-Dissolved			103.1		%		80-120	15-AUG-18
Rubidium (Rb)-Dissolved			101.7		%		80-120	15-AUG-18
Selenium (Se)-Dissolved			95.1		%		80-120	15-AUG-18
Silicon (Si)-Dissolved			101.7		%		60-140	15-AUG-18
Silver (Ag)-Dissolved			94.5		%		80-120	15-AUG-18
Sodium (Na)-Dissolved			103.6		%		80-120	15-AUG-18
Strontium (Sr)-Dissolved			105.2		%		80-120	15-AUG-18
Sulfur (S)-Dissolved			117.8		%		80-120	15-AUG-18
Tellurium (Te)-Dissolved			94.7		%		80-120	15-AUG-18
Thallium (Tl)-Dissolved			105.4		%		80-120	15-AUG-18
Thorium (Th)-Dissolved			91.5		%		80-120	15-AUG-18
Tin (Sn)-Dissolved			100.7		%		80-120	15-AUG-18
Titanium (Ti)-Dissolved			96.8		%		80-120	15-AUG-18
Tungsten (W)-Dissolved			110.5		%		80-120	15-AUG-18
Uranium (U)-Dissolved			95.2		%		80-120	15-AUG-18
Vanadium (V)-Dissolved			100.3		%		80-120	15-AUG-18
Zinc (Zn)-Dissolved			92.2		%		80-120	15-AUG-18
Zirconium (Zr)-Dissolved			98.4		%		80-120	15-AUG-18
WG2849455-2 LCS		**TMRM**						
Aluminum (Al)-Dissolved			102.6		%		80-120	14-AUG-18
Antimony (Sb)-Dissolved			108.5		%		80-120	14-AUG-18
Arsenic (As)-Dissolved			102.1		%		80-120	14-AUG-18
Barium (Ba)-Dissolved			101.2		%		80-120	14-AUG-18
Beryllium (Be)-Dissolved			99.4		%		80-120	14-AUG-18
Bismuth (Bi)-Dissolved			97.6		%		80-120	14-AUG-18
Cadmium (Cd)-Dissolved			101.5		%		80-120	14-AUG-18
Calcium (Ca)-Dissolved			105.9		%		80-120	14-AUG-18
Cesium (Cs)-Dissolved			97.3		%		80-120	14-AUG-18
Chromium (Cr)-Dissolved			101.0		%		80-120	14-AUG-18
Cobalt (Co)-Dissolved			103.1		%		80-120	14-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-2 LCS		**TMRM**						
Copper (Cu)-Dissolved			100.3		%		80-120	14-AUG-18
Iron (Fe)-Dissolved			116.0		%		80-120	14-AUG-18
Lead (Pb)-Dissolved			99.6		%		80-120	14-AUG-18
Lithium (Li)-Dissolved			101.0		%		80-120	14-AUG-18
Magnesium (Mg)-Dissolved			107.2		%		80-120	14-AUG-18
Manganese (Mn)-Dissolved			102.0		%		80-120	14-AUG-18
Molybdenum (Mo)-Dissolved			106.7		%		80-120	14-AUG-18
Nickel (Ni)-Dissolved			101.5		%		80-120	14-AUG-18
Phosphorus (P)-Dissolved			115.3		%		70-130	14-AUG-18
Potassium (K)-Dissolved			103.2		%		80-120	14-AUG-18
Rubidium (Rb)-Dissolved			104.9		%		80-120	14-AUG-18
Selenium (Se)-Dissolved			100.1		%		80-120	14-AUG-18
Silicon (Si)-Dissolved			103.2		%		60-140	14-AUG-18
Silver (Ag)-Dissolved			95.4		%		80-120	14-AUG-18
Sodium (Na)-Dissolved			105.5		%		80-120	14-AUG-18
Strontium (Sr)-Dissolved			104.9		%		80-120	14-AUG-18
Sulfur (S)-Dissolved			106.2		%		80-120	14-AUG-18
Tellurium (Te)-Dissolved			96.9		%		80-120	14-AUG-18
Thallium (Tl)-Dissolved			99.2		%		80-120	14-AUG-18
Thorium (Th)-Dissolved			89.0		%		80-120	14-AUG-18
Tin (Sn)-Dissolved			103.8		%		80-120	14-AUG-18
Titanium (Ti)-Dissolved			101.9		%		80-120	14-AUG-18
Tungsten (W)-Dissolved			106.3		%		80-120	14-AUG-18
Uranium (U)-Dissolved			91.3		%		80-120	14-AUG-18
Vanadium (V)-Dissolved			103.7		%		80-120	14-AUG-18
Zinc (Zn)-Dissolved			98.4		%		80-120	14-AUG-18
Zirconium (Zr)-Dissolved			99.8		%		80-120	14-AUG-18
WG2849455-4 LCS		**TMRM**						
Aluminum (Al)-Dissolved			104.8		%		80-120	15-AUG-18
Antimony (Sb)-Dissolved			113.6		%		80-120	15-AUG-18
Arsenic (As)-Dissolved			100.7		%		80-120	15-AUG-18
Barium (Ba)-Dissolved			102.9		%		80-120	15-AUG-18
Beryllium (Be)-Dissolved			102.8		%		80-120	15-AUG-18
Bismuth (Bi)-Dissolved			102.3		%		80-120	15-AUG-18

ALS Environmental

Quality Control Report

Workorder: L2134998 Report Date: 24-AUG-18

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-4 LCS		**TMRM**						
Cadmium (Cd)-Dissolved			100.6		%		80-120	15-AUG-18
Calcium (Ca)-Dissolved			101.7		%		80-120	15-AUG-18
Cesium (Cs)-Dissolved			96.6		%		80-120	15-AUG-18
Chromium (Cr)-Dissolved			103.0		%		80-120	15-AUG-18
Cobalt (Co)-Dissolved			104.2		%		80-120	15-AUG-18
Copper (Cu)-Dissolved			102.7		%		80-120	15-AUG-18
Iron (Fe)-Dissolved			117.5		%		80-120	15-AUG-18
Lead (Pb)-Dissolved			103.3		%		80-120	15-AUG-18
Lithium (Li)-Dissolved			104.6		%		80-120	15-AUG-18
Magnesium (Mg)-Dissolved			112.1		%		80-120	15-AUG-18
Manganese (Mn)-Dissolved			103.3		%		80-120	15-AUG-18
Molybdenum (Mo)-Dissolved			106.6		%		80-120	15-AUG-18
Nickel (Ni)-Dissolved			102.7		%		80-120	15-AUG-18
Phosphorus (P)-Dissolved			109.0		%		70-130	15-AUG-18
Potassium (K)-Dissolved			105.7		%		80-120	15-AUG-18
Rubidium (Rb)-Dissolved			108.4		%		80-120	15-AUG-18
Selenium (Se)-Dissolved			97.9		%		80-120	15-AUG-18
Silicon (Si)-Dissolved			104.2		%		60-140	15-AUG-18
Silver (Ag)-Dissolved			95.2		%		80-120	15-AUG-18
Sodium (Na)-Dissolved			103.8		%		80-120	15-AUG-18
Strontium (Sr)-Dissolved			104.1		%		80-120	15-AUG-18
Sulfur (S)-Dissolved			108.2		%		80-120	15-AUG-18
Tellurium (Te)-Dissolved			97.7		%		80-120	15-AUG-18
Thallium (Tl)-Dissolved			104.6		%		80-120	15-AUG-18
Thorium (Th)-Dissolved			93.9		%		80-120	15-AUG-18
Tin (Sn)-Dissolved			103.8		%		80-120	15-AUG-18
Titanium (Ti)-Dissolved			100.4		%		80-120	15-AUG-18
Tungsten (W)-Dissolved			105.7		%		80-120	15-AUG-18
Uranium (U)-Dissolved			96.7		%		80-120	15-AUG-18
Vanadium (V)-Dissolved			104.7		%		80-120	15-AUG-18
Zinc (Zn)-Dissolved			95.1		%		80-120	15-AUG-18
Zirconium (Zr)-Dissolved			100.1		%		80-120	15-AUG-18
WG2849455-9 LCS		**TMRM**						
Aluminum (Al)-Dissolved			102.2		%		80-120	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-9 LCS		**TMRM**						
Antimony (Sb)-Dissolved			107.7		%		80-120	15-AUG-18
Arsenic (As)-Dissolved			99.0		%		80-120	15-AUG-18
Barium (Ba)-Dissolved			98.8		%		80-120	15-AUG-18
Beryllium (Be)-Dissolved			95.8		%		80-120	15-AUG-18
Bismuth (Bi)-Dissolved			97.8		%		80-120	15-AUG-18
Cadmium (Cd)-Dissolved			97.6		%		80-120	15-AUG-18
Calcium (Ca)-Dissolved			99.8		%		80-120	15-AUG-18
Cesium (Cs)-Dissolved			94.6		%		80-120	15-AUG-18
Chromium (Cr)-Dissolved			101.4		%		80-120	15-AUG-18
Cobalt (Co)-Dissolved			100.6		%		80-120	15-AUG-18
Copper (Cu)-Dissolved			100.0		%		80-120	15-AUG-18
Iron (Fe)-Dissolved			112.8		%		80-120	15-AUG-18
Lead (Pb)-Dissolved			98.6		%		80-120	15-AUG-18
Lithium (Li)-Dissolved			98.4		%		80-120	15-AUG-18
Magnesium (Mg)-Dissolved			109.6		%		80-120	15-AUG-18
Manganese (Mn)-Dissolved			100.8		%		80-120	15-AUG-18
Molybdenum (Mo)-Dissolved			102.6		%		80-120	15-AUG-18
Nickel (Ni)-Dissolved			99.9		%		80-120	15-AUG-18
Phosphorus (P)-Dissolved			106.7		%		70-130	15-AUG-18
Potassium (K)-Dissolved			102.5		%		80-120	15-AUG-18
Rubidium (Rb)-Dissolved			101.3		%		80-120	15-AUG-18
Selenium (Se)-Dissolved			95.2		%		80-120	15-AUG-18
Silicon (Si)-Dissolved			101.2		%		60-140	15-AUG-18
Silver (Ag)-Dissolved			93.6		%		80-120	15-AUG-18
Sodium (Na)-Dissolved			107.0		%		80-120	15-AUG-18
Strontium (Sr)-Dissolved			103.3		%		80-120	15-AUG-18
Sulfur (S)-Dissolved			114.2		%		80-120	15-AUG-18
Tellurium (Te)-Dissolved			90.8		%		80-120	15-AUG-18
Thallium (Tl)-Dissolved			99.5		%		80-120	15-AUG-18
Thorium (Th)-Dissolved			86.2		%		80-120	15-AUG-18
Tin (Sn)-Dissolved			100.2		%		80-120	15-AUG-18
Titanium (Ti)-Dissolved			103.3		%		80-120	15-AUG-18
Tungsten (W)-Dissolved			105.3		%		80-120	15-AUG-18
Uranium (U)-Dissolved			91.1		%		80-120	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-9 LCS		**TMRM**						
Vanadium (V)-Dissolved			102.3		%		80-120	15-AUG-18
Zinc (Zn)-Dissolved			93.8		%		80-120	15-AUG-18
Zirconium (Zr)-Dissolved			97.4		%		80-120	15-AUG-18
WG2849455-1 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	14-AUG-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	14-AUG-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	14-AUG-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	14-AUG-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	14-AUG-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	14-AUG-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	14-AUG-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	14-AUG-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	14-AUG-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	14-AUG-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	14-AUG-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	14-AUG-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	14-AUG-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	14-AUG-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	14-AUG-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	14-AUG-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	14-AUG-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	14-AUG-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	14-AUG-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	14-AUG-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	14-AUG-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	14-AUG-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	14-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-1 MB								
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	14-AUG-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	14-AUG-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	14-AUG-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	14-AUG-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	14-AUG-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	14-AUG-18
WG2849455-11 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	15-AUG-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	15-AUG-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	15-AUG-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-11 MB								
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	15-AUG-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	15-AUG-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	15-AUG-18
WG2849455-3 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	15-AUG-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	15-AUG-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	15-AUG-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-3 MB								
Potassium (K)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	15-AUG-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	15-AUG-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	15-AUG-18
WG2849455-8 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Cadmium (Cd)-Dissolved			<0.000005C		mg/L		0.000005	15-AUG-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	15-AUG-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4169221								
WG2849455-8 MB								
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	15-AUG-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	15-AUG-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	15-AUG-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	15-AUG-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	15-AUG-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	15-AUG-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	15-AUG-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	15-AUG-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	15-AUG-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	15-AUG-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	15-AUG-18
MET-T-CCMS-CL	Water							
Batch R4159507								
WG2841741-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	04-AUG-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	04-AUG-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	04-AUG-18
Calcium (Ca)-Total			<0.050		mg/L		0.05	04-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4159507								
WG2841741-1 MB								
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	04-AUG-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	04-AUG-18
Iron (Fe)-Total			<0.010		mg/L		0.01	04-AUG-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	04-AUG-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	04-AUG-18
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	04-AUG-18
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	04-AUG-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	04-AUG-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	04-AUG-18
Potassium (K)-Total			<0.050		mg/L		0.05	04-AUG-18
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	04-AUG-18
Selenium (Se)-Total			<0.000050		mg/L		0.00005	04-AUG-18
Silicon (Si)-Total			<0.10		mg/L		0.1	04-AUG-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	04-AUG-18
Sodium (Na)-Total			<0.050		mg/L		0.05	04-AUG-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	04-AUG-18
Sulfur (S)-Total			<0.50		mg/L		0.5	04-AUG-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	04-AUG-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	04-AUG-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Tin (Sn)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	04-AUG-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	04-AUG-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	04-AUG-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	04-AUG-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	04-AUG-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	04-AUG-18
Batch R4159880								
WG2841741-5 LCS		**TMRM**						
Aluminum (Al)-Total			99.0		%		80-120	06-AUG-18
Antimony (Sb)-Total			98.0		%		80-120	06-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4159880								
WG2841741-5 LCS		**TMRM**						
Arsenic (As)-Total			98.6		%		80-120	06-AUG-18
Barium (Ba)-Total			98.5		%		80-120	06-AUG-18
Beryllium (Be)-Total			99.4		%		80-120	06-AUG-18
Bismuth (Bi)-Total			92.0		%		80-120	06-AUG-18
Cadmium (Cd)-Total			102.2		%		80-120	06-AUG-18
Calcium (Ca)-Total			102.3		%		80-120	06-AUG-18
Cesium (Cs)-Total			96.7		%		80-120	06-AUG-18
Chromium (Cr)-Total			98.3		%		80-120	06-AUG-18
Cobalt (Co)-Total			98.1		%		80-120	06-AUG-18
Copper (Cu)-Total			96.3		%		80-120	06-AUG-18
Iron (Fe)-Total			102.9		%		80-120	06-AUG-18
Lead (Pb)-Total			95.3		%		80-120	06-AUG-18
Lithium (Li)-Total			99.6		%		80-120	06-AUG-18
Magnesium (Mg)-Total			97.5		%		80-120	06-AUG-18
Manganese (Mn)-Total			95.0		%		80-120	06-AUG-18
Molybdenum (Mo)-Total			103.9		%		80-120	06-AUG-18
Nickel (Ni)-Total			93.6		%		80-120	06-AUG-18
Phosphorus (P)-Total			103.0		%		70-130	06-AUG-18
Potassium (K)-Total			93.6		%		80-120	06-AUG-18
Rubidium (Rb)-Total			95.5		%		80-120	06-AUG-18
Selenium (Se)-Total			100.5		%		80-120	06-AUG-18
Silicon (Si)-Total			107.0		%		60-140	06-AUG-18
Silver (Ag)-Total			98.1		%		80-120	06-AUG-18
Sodium (Na)-Total			99.6		%		80-120	06-AUG-18
Strontium (Sr)-Total			101.7		%		80-120	06-AUG-18
Sulfur (S)-Total			98.6		%		80-120	06-AUG-18
Tellurium (Te)-Total			95.4		%		80-120	06-AUG-18
Thallium (Tl)-Total			90.1		%		80-120	06-AUG-18
Thorium (Th)-Total			98.1		%		80-120	06-AUG-18
Tin (Sn)-Total			98.1		%		80-120	06-AUG-18
Titanium (Ti)-Total			98.1		%		80-120	06-AUG-18
Tungsten (W)-Total			104.8		%		80-120	06-AUG-18
Uranium (U)-Total			101.7		%		80-120	06-AUG-18
Vanadium (V)-Total			96.6		%		80-120	06-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4159880								
WG2841741-5 LCS		**TMRM**						
Zinc (Zn)-Total			98.0		%		80-120	06-AUG-18
Zirconium (Zr)-Total			105.4		%		80-120	06-AUG-18
WG2841741-4 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	06-AUG-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	06-AUG-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	06-AUG-18
Calcium (Ca)-Total			<0.050		mg/L		0.05	06-AUG-18
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	06-AUG-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	06-AUG-18
Iron (Fe)-Total			<0.010		mg/L		0.01	06-AUG-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	06-AUG-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	06-AUG-18
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	06-AUG-18
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	06-AUG-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	06-AUG-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	06-AUG-18
Potassium (K)-Total			<0.050		mg/L		0.05	06-AUG-18
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	06-AUG-18
Selenium (Se)-Total			<0.000050		mg/L		0.00005	06-AUG-18
Silicon (Si)-Total			<0.10		mg/L		0.1	06-AUG-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	06-AUG-18
Sodium (Na)-Total			<0.050		mg/L		0.05	06-AUG-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	06-AUG-18
Sulfur (S)-Total			<0.50		mg/L		0.5	06-AUG-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	06-AUG-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	06-AUG-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	06-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4159880								
WG2841741-4 MB								
Tin (Sn)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	06-AUG-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	06-AUG-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	06-AUG-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	06-AUG-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	06-AUG-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	06-AUG-18
Batch R4160413								
WG2841741-8 LCS		**TMRM**						
Aluminum (Al)-Total			100.0		%		80-120	08-AUG-18
Antimony (Sb)-Total			99.4		%		80-120	08-AUG-18
Arsenic (As)-Total			99.1		%		80-120	08-AUG-18
Barium (Ba)-Total			100.3		%		80-120	08-AUG-18
Beryllium (Be)-Total			98.7		%		80-120	08-AUG-18
Bismuth (Bi)-Total			96.6		%		80-120	08-AUG-18
Cadmium (Cd)-Total			101.4		%		80-120	08-AUG-18
Calcium (Ca)-Total			89.9		%		80-120	08-AUG-18
Cesium (Cs)-Total			105.9		%		80-120	08-AUG-18
Chromium (Cr)-Total			98.9		%		80-120	08-AUG-18
Cobalt (Co)-Total			98.6		%		80-120	08-AUG-18
Copper (Cu)-Total			99.1		%		80-120	08-AUG-18
Iron (Fe)-Total			102.1		%		80-120	08-AUG-18
Lead (Pb)-Total			95.3		%		80-120	08-AUG-18
Lithium (Li)-Total			95.6		%		80-120	08-AUG-18
Magnesium (Mg)-Total			102.2		%		80-120	08-AUG-18
Manganese (Mn)-Total			97.1		%		80-120	08-AUG-18
Molybdenum (Mo)-Total			90.5		%		80-120	08-AUG-18
Nickel (Ni)-Total			99.0		%		80-120	08-AUG-18
Phosphorus (P)-Total			99.2		%		70-130	08-AUG-18
Potassium (K)-Total			99.5		%		80-120	08-AUG-18
Rubidium (Rb)-Total			100.1		%		80-120	08-AUG-18
Selenium (Se)-Total			96.2		%		80-120	08-AUG-18
Silicon (Si)-Total			100.0		%		60-140	08-AUG-18
Silver (Ag)-Total			108.1		%		80-120	08-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4160413								
WG2841741-8 LCS		**TMRM**						
Sodium (Na)-Total			99.9		%		80-120	08-AUG-18
Strontium (Sr)-Total			85.0		%		80-120	08-AUG-18
Sulfur (S)-Total			93.5		%		80-120	08-AUG-18
Tellurium (Te)-Total			103.8		%		80-120	08-AUG-18
Thallium (Tl)-Total			97.0		%		80-120	08-AUG-18
Thorium (Th)-Total			100.2		%		80-120	08-AUG-18
Tin (Sn)-Total			102.0		%		80-120	08-AUG-18
Titanium (Ti)-Total			92.3		%		80-120	08-AUG-18
Tungsten (W)-Total			109.6		%		80-120	08-AUG-18
Uranium (U)-Total			103.8		%		80-120	08-AUG-18
Vanadium (V)-Total			99.7		%		80-120	08-AUG-18
Zinc (Zn)-Total			98.6		%		80-120	08-AUG-18
Zirconium (Zr)-Total			92.2		%		80-120	08-AUG-18
WG2841741-7 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	08-AUG-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	08-AUG-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	08-AUG-18
Calcium (Ca)-Total			<0.050		mg/L		0.05	08-AUG-18
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	08-AUG-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	08-AUG-18
Iron (Fe)-Total			<0.010		mg/L		0.01	08-AUG-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	08-AUG-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	08-AUG-18
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	08-AUG-18
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	08-AUG-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	08-AUG-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	08-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4160413								
WG2841741-7 MB								
Potassium (K)-Total			<0.050		mg/L		0.05	08-AUG-18
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	08-AUG-18
Selenium (Se)-Total			<0.000050		mg/L		0.00005	08-AUG-18
Silicon (Si)-Total			<0.10		mg/L		0.1	08-AUG-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	08-AUG-18
Sodium (Na)-Total			<0.050		mg/L		0.05	08-AUG-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	08-AUG-18
Sulfur (S)-Total			<0.50		mg/L		0.5	08-AUG-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	08-AUG-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	08-AUG-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Tin (Sn)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	08-AUG-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	08-AUG-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	08-AUG-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	08-AUG-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	08-AUG-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	08-AUG-18
Batch R4169221								
WG2841741-3 DUP		**L2134998-1**						
Aluminum (Al)-Total		0.037	0.038		mg/L	1.2	20	15-AUG-18
Antimony (Sb)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Arsenic (As)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Barium (Ba)-Total		0.0418	0.0428		mg/L	2.5	20	15-AUG-18
Beryllium (Be)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Bismuth (Bi)-Total		<0.00025	<0.00025	RPD-NA	mg/L	N/A	20	15-AUG-18
Cadmium (Cd)-Total		<0.000025	<0.000025	RPD-NA	mg/L	N/A	20	15-AUG-18
Calcium (Ca)-Total		45.6	46.5		mg/L	2.0	20	15-AUG-18
Cesium (Cs)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	15-AUG-18
Chromium (Cr)-Total		0.00056	0.00066		mg/L	17	20	15-AUG-18
Cobalt (Co)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Copper (Cu)-Total		<0.0025	<0.0025	RPD-NA	mg/L	N/A	20	15-AUG-18
Iron (Fe)-Total		0.152	0.158		mg/L	3.5	20	15-AUG-18
Lead (Pb)-Total		<0.00025	<0.00025	RPD-NA	mg/L	N/A	20	15-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4169221								
WG2841741-3 DUP		**L2134998-1**						
Lithium (Li)-Total		0.0103	0.0108		mg/L	4.7	20	15-AUG-18
Magnesium (Mg)-Total		12.6	13.2		mg/L	4.7	20	15-AUG-18
Manganese (Mn)-Total		0.0152	0.0151		mg/L	0.5	20	15-AUG-18
Molybdenum (Mo)-Total		<0.00025	0.00027	RPD-NA	mg/L	N/A	20	15-AUG-18
Nickel (Ni)-Total		<0.0025	<0.0025	RPD-NA	mg/L	N/A	20	15-AUG-18
Phosphorus (P)-Total		<0.25	<0.25	RPD-NA	mg/L	N/A	20	15-AUG-18
Potassium (K)-Total		2.00	2.07		mg/L	3.3	20	15-AUG-18
Rubidium (Rb)-Total		0.0016	0.0016		mg/L	1.2	20	15-AUG-18
Selenium (Se)-Total		<0.00025	<0.00025	RPD-NA	mg/L	N/A	20	15-AUG-18
Silicon (Si)-Total		3.36	3.45		mg/L	2.9	20	15-AUG-18
Silver (Ag)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	15-AUG-18
Sodium (Na)-Total		13.0	13.4		mg/L	3.5	20	15-AUG-18
Strontium (Sr)-Total		0.130	0.131		mg/L	0.7	20	15-AUG-18
Sulfur (S)-Total		8.2	8.0		mg/L	2.5	20	15-AUG-18
Tellurium (Te)-Total		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	15-AUG-18
Thallium (Tl)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	15-AUG-18
Thorium (Th)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Tin (Sn)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Titanium (Ti)-Total		<0.0015	<0.0015	RPD-NA	mg/L	N/A	20	15-AUG-18
Tungsten (W)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	15-AUG-18
Uranium (U)-Total		0.000209	0.000195		mg/L	7.1	20	15-AUG-18
Vanadium (V)-Total		<0.0025	<0.0025	RPD-NA	mg/L	N/A	20	15-AUG-18
Zinc (Zn)-Total		<0.015	<0.015	RPD-NA	mg/L	N/A	20	15-AUG-18
Zirconium (Zr)-Total		<0.00030	<0.00030	RPD-NA	mg/L	N/A	20	15-AUG-18
NAPHTHENIC ACID-L-FM	Water							
Batch R4158897								
WG2840308-8 DUP		**L2134998-1**						
Naphthenic Acids		0.29	0.27		mg/L	7.0	30	03-AUG-18
WG2840308-6 LCS								
Naphthenic Acids			101.3		%		70-130	03-AUG-18
WG2840308-5 MB								
Naphthenic Acids			<0.10		mg/L		0.1	03-AUG-18
WG2840308-7 MS		**L2134998-5**						
Naphthenic Acids			62.5		%		50-150	03-AUG-18
NH3-COL-ED	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-COL-ED	Water							
Batch R4151740								
WG2837742-2 LCS								
Ammonia, Total (as N)			112.3		%		85-115	31-JUL-18
WG2837742-8 LCS								
Ammonia, Total (as N)			100.9		%		85-115	31-JUL-18
WG2837742-1 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	31-JUL-18
WG2837742-7 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	31-JUL-18
Batch R4152602								
WG2838727-10 LCS								
Ammonia, Total (as N)			101.4		%		85-115	01-AUG-18
WG2838727-2 LCS								
Ammonia, Total (as N)			98.4		%		85-115	01-AUG-18
WG2838727-6 LCS								
Ammonia, Total (as N)			102.1		%		85-115	01-AUG-18
WG2838727-8 LCS								
Ammonia, Total (as N)			107.4		%		85-115	01-AUG-18
WG2838727-1 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	01-AUG-18
WG2838727-5 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	01-AUG-18
WG2838727-7 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	01-AUG-18
WG2838727-9 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	01-AUG-18
NO2-IC-N-ED	Water							
Batch R4140058								
WG2831434-11 LCS								
Nitrite (as N)			104.7		%		90-110	25-JUL-18
WG2831434-13 LCS								
Nitrite (as N)			105.5		%		90-110	25-JUL-18
WG2831434-15 LCS								
Nitrite (as N)			105.6		%		90-110	25-JUL-18
WG2831434-17 LCS								
Nitrite (as N)			106.0		%		90-110	25-JUL-18
WG2831434-2 LCS								
Nitrite (as N)			104.2		%		90-110	25-JUL-18
WG2831434-1 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-IC-N-ED	Water							
Batch R4140058								
WG2831434-1 MB								
Nitrite (as N)			<0.010		mg/L		0.01	25-JUL-18
WG2831434-12 MB								
Nitrite (as N)			<0.010		mg/L		0.01	25-JUL-18
WG2831434-14 MB								
Nitrite (as N)			<0.010		mg/L		0.01	25-JUL-18
WG2831434-16 MB								
Nitrite (as N)			<0.010		mg/L		0.01	25-JUL-18
WG2831434-18 MB								
Nitrite (as N)			<0.010		mg/L		0.01	25-JUL-18
NO3-IC-N-ED	Water							
Batch R4140058								
WG2831434-11 LCS								
Nitrate (as N)			101.2		%		90-110	25-JUL-18
WG2831434-13 LCS								
Nitrate (as N)			101.2		%		90-110	25-JUL-18
WG2831434-15 LCS								
Nitrate (as N)			101.1		%		90-110	25-JUL-18
WG2831434-17 LCS								
Nitrate (as N)			101.1		%		90-110	25-JUL-18
WG2831434-2 LCS								
Nitrate (as N)			100.3		%		90-110	25-JUL-18
WG2831434-1 MB								
Nitrate (as N)			<0.020		mg/L		0.02	25-JUL-18
WG2831434-12 MB								
Nitrate (as N)			<0.020		mg/L		0.02	25-JUL-18
WG2831434-14 MB								
Nitrate (as N)			<0.020		mg/L		0.02	25-JUL-18
WG2831434-16 MB								
Nitrate (as N)			<0.020		mg/L		0.02	25-JUL-18
WG2831434-18 MB								
Nitrate (as N)			<0.020		mg/L		0.02	25-JUL-18
P-T-L-COL-ED	Water							
Batch R4178596								
WG2853120-2 LCS								
Phosphorus (P)-Total			97.2		%		80-120	20-AUG-18
WG2853120-1 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	20-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
P-TD-L-COL-ED	Water							
Batch R4178596								
WG2853120-2 LCS								
Phosphorus (P)-Total Dissolved			96.0		%		80-120	20-AUG-18
WG2853120-1 MB								
Phosphorus (P)-Total Dissolved			<0.0010		mg/L		0.001	20-AUG-18
PH/EC/ALKS-ED	Water							
Batch R4159313								
WG2841731-37 DUP		**L2134998-1**						
pH		8.21	8.22	J	pH	0.01	0.3	04-AUG-18
Conductivity (EC)		325	321		uS/cm	1.2	10	04-AUG-18
Bicarbonate Alkalinity (as HCO3)		190	188		mg/L	1.0	25	04-AUG-18
Carbonate Alkalinity (as CO3)		<5.0	<5.0	RPD-NA	mg/L	N/A	25	04-AUG-18
Hydroxide Alkalinity (as OH)		<5.0	<5.0	RPD-NA	mg/L	N/A	25	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)		<2.0	<2.0	RPD-NA	mg/L	N/A	25	04-AUG-18
Alkalinity, Total (as CaCO3)		156	154		mg/L	1.0	20	04-AUG-18
WG2841731-10 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			95.1		%		85-115	04-AUG-18
WG2841731-11 LCS		**HI_12890**						
Conductivity (EC)			94.3		%		90-110	04-AUG-18
WG2841731-13 LCS		**MID_1412**						
Conductivity (EC)			95.9		%		90-110	04-AUG-18
WG2841731-14 LCS		**ED-PH6**						
pH			6.00		pH		5.8-6.2	04-AUG-18
WG2841731-15 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			97.8		%		85-115	04-AUG-18
WG2841731-16 LCS		**HI_12890**						
Conductivity (EC)			93.6		%		90-110	04-AUG-18
WG2841731-18 LCS		**MID_1412**						
Conductivity (EC)			97.2		%		90-110	04-AUG-18
WG2841731-19 LCS		**ED-PH6**						
pH			6.01		pH		5.8-6.2	04-AUG-18
WG2841731-2 LCS		**MID_1412**						
Conductivity (EC)			94.5		%		90-110	04-AUG-18
WG2841731-20 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			98.1		%		85-115	04-AUG-18
WG2841731-21 LCS		**HI_12890**						
Conductivity (EC)			95.1		%		90-110	04-AUG-18
WG2841731-23 LCS		**MID_1412**						
Conductivity (EC)			98.0		%		90-110	04-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH/EC/ALKS-ED	Water							
Batch R4159313								
WG2841731-24 LCS		**ED-PH6**						
pH			6.00		pH		5.8-6.2	04-AUG-18
WG2841731-25 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			96.9		%		85-115	04-AUG-18
WG2841731-26 LCS		**HI_12890**						
Conductivity (EC)			95.8		%		90-110	04-AUG-18
WG2841731-28 LCS		**MID_1412**						
Conductivity (EC)			97.0		%		90-110	04-AUG-18
WG2841731-29 LCS		**ED-PH6**						
pH			6.00		pH		5.8-6.2	04-AUG-18
WG2841731-3 LCS		**ED-PH6**						
pH			6.05		pH		5.8-6.2	04-AUG-18
WG2841731-30 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			96.2		%		85-115	04-AUG-18
WG2841731-31 LCS		**HI_12890**						
Conductivity (EC)			95.3		%		90-110	04-AUG-18
WG2841731-4 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			95.1		%		85-115	04-AUG-18
WG2841731-5 LCS		**HI_12890**						
Conductivity (EC)			93.5		%		90-110	04-AUG-18
WG2841731-8 LCS		**MID_1412**						
Conductivity (EC)			94.7		%		90-110	04-AUG-18
WG2841731-9 LCS		**ED-PH6**						
pH			6.02		pH		5.8-6.2	04-AUG-18
WG2841731-1 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18
WG2841731-12 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18

ALS Environmental

Quality Control Report

Workorder: L2134998 Report Date: 24-AUG-18

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH/EC/ALKS-ED	Water							
Batch R4159313								
WG2841731-17 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18
WG2841731-22 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18
WG2841731-27 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18
WG2841731-7 MB								
Conductivity (EC)			<2.0		uS/cm		2	04-AUG-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	04-AUG-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	04-AUG-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	04-AUG-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	04-AUG-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	04-AUG-18
PHENOLS-4AAP-WT	Water							
Batch R4153713								
WG2839017-11 DUP		**L2134998-1**						
Phenols (4AAP)		0.0018	0.0015		mg/L	17	20	01-AUG-18
WG2839017-10 LCS								
Phenols (4AAP)			99.2		%		85-115	01-AUG-18
WG2839017-2 LCS								
Phenols (4AAP)			95.2		%		85-115	01-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PHENOLS-4AAP-WT	Water							
Batch R4153713								
WG2839017-1 MB								
Phenols (4AAP)			<0.0010		mg/L		0.001	01-AUG-18
WG2839017-9 MB								
Phenols (4AAP)			<0.0010		mg/L		0.001	01-AUG-18
WG2839017-12 MS		**L2134998-1**						
Phenols (4AAP)			89.7		%		75-125	01-AUG-18
Batch R4158089								
WG2839973-2 LCS								
Phenols (4AAP)			99.9		%		85-115	03-AUG-18
WG2839973-1 MB								
Phenols (4AAP)			<0.0010		mg/L		0.001	03-AUG-18
PO4-DO-COL-ED	Water							
Batch R4139994								
WG2832008-2 LCS								
Orthophosphate-Dissolved (as P)			103.3		%		80-120	25-JUL-18
WG2832008-1 MB								
Orthophosphate-Dissolved (as P)			<0.010		mg/L		0.01	25-JUL-18
SO4-IC-N-ED	Water							
Batch R4140058								
WG2831434-11 LCS								
Sulfate (SO4)			103.0		%		90-110	25-JUL-18
WG2831434-13 LCS								
Sulfate (SO4)			102.9		%		90-110	25-JUL-18
WG2831434-15 LCS								
Sulfate (SO4)			103.1		%		90-110	25-JUL-18
WG2831434-17 LCS								
Sulfate (SO4)			103.0		%		90-110	25-JUL-18
WG2831434-2 LCS								
Sulfate (SO4)			103.8		%		90-110	25-JUL-18
WG2831434-1 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	25-JUL-18
WG2831434-12 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	25-JUL-18
WG2831434-14 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	25-JUL-18
WG2831434-16 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	25-JUL-18
WG2831434-18 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SO4-IC-N-ED	Water							
Batch R4140058								
WG2831434-18 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	25-JUL-18
SOLIDS-TDS-ED	Water							
Batch R4152878								
WG2838010-2 LCS								
Total Dissolved Solids			96.8		%		85-115	31-JUL-18
WG2838010-1 MB								
Total Dissolved Solids			<10		mg/L		10	31-JUL-18
SOLIDS-TOTSUS-ED	Water							
Batch R4152825								
WG2837971-2 LCS								
Total Suspended Solids			91.6		%		85-115	31-JUL-18
WG2837971-1 MB								
Total Suspended Solids			<3.0		mg/L		3	31-JUL-18
TKN-CFA-ED	Water							
Batch R4173328								
WG2850635-6 LCS								
Total Kjeldahl Nitrogen			99		%		75-125	16-AUG-18
WG2850635-5 MB								
Total Kjeldahl Nitrogen			<0.20		mg/L		0.2	16-AUG-18
Batch R4175708								
WG2851643-2 LCS								
Total Kjeldahl Nitrogen			100		%		75-125	17-AUG-18
WG2851643-1 MB								
Total Kjeldahl Nitrogen			<0.20		mg/L		0.2	17-AUG-18

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Inorganic Parameters							
Chlorine, Total							
	1	24-JUL-18 12:30	25-JUL-18 10:00	0.25	22	hours	EHTR-FM
	2	24-JUL-18 13:00	25-JUL-18 10:00	0.25	21	hours	EHTR-FM
	3	24-JUL-18 14:40	25-JUL-18 10:00	0.25	19	hours	EHTR-FM
	4	24-JUL-18 14:40	25-JUL-18 10:00	0.25	19	hours	EHTR-FM
	5	24-JUL-18 12:30	25-JUL-18 10:00	0.25	22	hours	EHTR-FM
Aggregate Organics							
Hydrocarbons,Rec. (I.R.)							
	1	24-JUL-18 12:30	23-AUG-18 07:00	28	30	days	EHT
	2	24-JUL-18 13:00	23-AUG-18 07:00	28	30	days	EHT
	3	24-JUL-18 14:40	23-AUG-18 07:00	28	30	days	EHT
	4	24-JUL-18 14:40	23-AUG-18 07:00	28	30	days	EHT
	5	24-JUL-18 12:30	23-AUG-18 07:00	28	30	days	EHT

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L2134998 were received on 24-JUL-18 16:50.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

s.19(1)

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L2134998-COFC

COC Number:

Page 1 of 1

Report To
Company: HATFIELD CONSULTANTS
Contact: Chris Jaeggle or Andrew O'Gorman
Address: Suite A, 300 MacKenzie Blvd, Fort McMurray, AB T9H 4C4
Phone: 604-330-2474 or 780-743-4290

Report Format / Distribution
Select Report Format: ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL)
Quality Control (QC) Report with Report ☑ Yes ☐ No
☐ Criteria on Report - provide details below if box checked
Select Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax
Email 2

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)
R ☑ Regular (Standard TAT if received by 3 pm - business days)
P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge
Specify Date Required for E2,E or P:

Invoice To Same as Report To ☑ Yes ☐ No
Copy of Invoice with Report ☐ Yes ☐ No
Company:
Contact:

Invoice Distribution
Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax: Same as report
Email 2

Project Information
ALS Quote #: Q69154
Job #:
PO / AFE: CNUL9184
LSD:

Oil and Gas Required Fields (client use)
Approver ID: | Cost Center:
GL Account: | Routing Code:
Activity Code:
Location:

ALS Lab Work Order # (lab use only)

ALS Contact:
Sampler: HK, AO

Analysis Request
Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Q69154	Number of Containers
	BUOY TOP	24-JUL-18	12:30	SW	✓	12
	BUOY BOTTOM	24-JUL-18	13:00	SW	✓	12
	OUTLET	24-JUL-18	14:40	SW	✓	12
	DUPLICATE	24-JUL-18	14:40	SW	✓	12
	TB (trip blank)	24-JUL-18			✓	9

Drinking Water (DW) Samples[1] (client use)
Are samples taken from a Regulated DW System? ☐ Yes ☑ No
Are samples for human drinking water use? ☐ Yes ☑ No

Special Instructions / Specify Criteria to add on report (client Use)
All dissolved parameters are not field filtered and not preserved in all bottle sets.

SAMPLE CONDITION AS RECEIVED (lab use only)
Frozen ☐ SIF Observations Yes ☐ No ☐
Ice packs Yes ☐ No ☐ Custody seal intact Yes ☐ No ☐
Cooling Initiated ☐
INITIAL COOLER TEMPERATURES °C: 15°C
FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date: 24-JUL-18	Time: 16:51	Received by:	Date: Jul 24/18	Time: 4:50	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY — YELLOW - CLIENT COPY

NA-FM-0326e v09 Front/04 January 2014

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

ALS

Hatfield Consultants
ATTN: Chris Jaeggle
200-580 Harbourside Drive
North Vancouver BC V7P 0A3

Date Received: 13-SEP-18
Report Date: 11-DEC-18 15:52 (MT)
Version: FINAL REV. 3

Client Phone: 604-926-3261

Certificate of Analysis

Lab Work Order #: L2164033
Project P.O. #: CNUL9184
Job Reference:
C of C Numbers:
Legal Site Desc:

Comments: ADDITIONAL 07-DEC-18 09:46.

Dana Brown, Chem. Tech. DIPL
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-1 BUOY TOP							
Sampled By: CLIENT on 13-SEP-18 @ 10:00							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	3.71		0.10	ug/L	14-SEP-18	14-SEP-18	R4254067
GROUP 1 - RAMP							
Color, True							
Color, True	37.4		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	110			%		03-OCT-18	
TDS (Calculated)	197			mg/L		03-OCT-18	
Hardness (as CaCO3)	175			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	8.13		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	318		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	197		5.0	mg/L		15-SEP-18	R4216885
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	161		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	4.36		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							
Sulfate (SO4)	18.7		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							
Total Kjeldahl Nitrogen	0.53		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0087		0.0010	mg/L		18-SEP-18	R4220108
Total P in Water by Colour							
Phosphorus (P)-Total	0.0137		0.0010	mg/L		18-SEP-18	R4220108
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		25-SEP-18	R4242690
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	49.2		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	0.052		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	12.7		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	<0.0050		0.0050	mg/L		03-OCT-18	R4258599
Potassium (K)-Dissolved	2.09		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	13.3		1.0	mg/L		03-OCT-18	R4258599
Total Metals							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-1 BUOY TOP							
Sampled By: CLIENT on 13-SEP-18 @ 10:00							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0155		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	0.00035		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Total	0.0413		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Total	0.075		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	0.00016		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Lead (Pb)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	0.0101		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	0.000360		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	0.00098		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	<0.050		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	0.00151		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	0.000060		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	3.62		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Total	0.129		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	7.23		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	0.000234		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	0.000210		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	46.6		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	0.188		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	12.1		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	0.0655		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	2.05		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	13.3		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	17.1		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	<0.10		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	0.0014		0.0010	mg/L		21-SEP-18	R4231049
Boron (B)-Total	0.0747		0.0020	mg/L		02-OCT-18	R4258478
Total Dissolved Solids	216		12	mg/L		19-SEP-18	R4227997
Mercury (Hg)-Total	0.00067		0.00050	ug/L		21-SEP-18	R4232461
Total Organic Carbon	17.2		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	<3.0		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-1 BUOY TOP							
Sampled By: CLIENT on 13-SEP-18 @ 10:00							
Matrix: SW							
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-OCT-18	R4254492
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-OCT-18	02-OCT-18	R4257841
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	0.0670		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	0.00036		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	0.0406		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	0.067		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	40.5		0.50	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	0.00031		0.00020	mg/L		02-OCT-18	R4258478
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Dissolved	0.0083		0.0010	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	12.5		0.10	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	0.000337		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	0.00090		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Dissolved	<0.050		0.050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	1.97		0.50	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Dissolved	0.00144		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	0.000058		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	3.56		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	12.6		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	0.124		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Dissolved	7.47		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Dissolved	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	0.000212		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Dissolved	0.000181		0.000060	mg/L		02-OCT-18	R4258478
L2164033-2 BUOY BOTTOM							
Sampled By: CLIENT on 13-SEP-18 @ 11:00							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	1.15		0.10	ug/L	14-SEP-18	14-SEP-18	R4254067
GROUP 1 - RAMP							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-2 BUOY BOTTOM							
Sampled By: CLIENT on 13-SEP-18 @ 11:00							
Matrix: SW							
Color, True							
Color, True	131		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	114	BL:INT		%		03-OCT-18	
TDS (Calculated)	201			mg/L		03-OCT-18	
Hardness (as CaCO3)	181			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	7.90		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	331		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	199		5.0	mg/L		15-SEP-18	R4216885
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	163		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	5.14		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							
Sulfate (SO4)	17.4		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	0.415		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							
Total Kjeldahl Nitrogen	0.95		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0533		0.0010	mg/L		18-SEP-18	R4220108
Total P in Water by Colour							
Phosphorus (P)-Total	0.0576		0.0010	mg/L		18-SEP-18	R4220108
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		25-SEP-18	R4242690
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	51.2		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	3.52		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	12.8		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	0.825		0.0050	mg/L		03-OCT-18	R4258599
Potassium (K)-Dissolved	2.24		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	14.2		1.0	mg/L		03-OCT-18	R4258599
Total Metals							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0751		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	0.00086		0.00010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-2 BUOY BOTTOM							
Sampled By: CLIENT on 13-SEP-18 @ 11:00							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Barium (Ba)-Total	0.0538		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	0.000010		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	0.00023		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	0.00091		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Lead (Pb)-Total	0.000086		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	0.0100		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	0.000604		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	0.00146		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	0.122		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	0.00144		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	0.000068		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	4.71		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Total	0.130		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	6.86		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	0.00214		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	0.000300		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	0.00116		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	0.000806		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	47.1		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	4.56		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	11.9		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	0.854		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	2.19		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	13.8		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	0.041		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	18.0		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	0.76		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	0.0040		0.0010	mg/L		21-SEP-18	R4231049
Boron (B)-Total	0.0831		0.0020	mg/L		02-OCT-18	R4258478
Total Dissolved Solids	222		12	mg/L		19-SEP-18	R4227997
Mercury (Hg)-Total	0.00140		0.00050	ug/L		21-SEP-18	R4232461
Total Organic Carbon	18.2		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	6.7		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-OCT-18	R4254492
Mercury (Hg)-Dissolved	0.00070		0.00050	ug/L	01-OCT-18	02-OCT-18	R4257841
Dissolved Boron by CRC CCMS							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-2 BUOY BOTTOM							
Sampled By: CLIENT on 13-SEP-18 @ 11:00							
Matrix: SW							
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	0.0771		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	0.0030	RRV	0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	0.00092		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	0.0520		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	0.077		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	43.6		0.50	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	0.00067		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	0.00025		0.00020	mg/L		02-OCT-18	R4258478
Iron (Fe)-Dissolved	3.54		0.010	mg/L		02-OCT-18	R4258478
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	12.4		0.10	mg/L		02-OCT-18	R4258478
Manganese (Mn)-Dissolved	0.788		0.00010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	0.000583		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	0.00127		0.00050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	2.11		0.50	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	0.000066		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	4.41		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	13.4		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	0.129		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	0.000275		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	0.00070		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	0.0011		0.0010	mg/L		02-OCT-18	R4258478
L2164033-3 OUTLET							
Sampled By: CLIENT on 13-SEP-18 @ 11:45							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	3.83		0.10	ug/L	14-SEP-18	14-SEP-18	R4254067
GROUP 1 - RAMP							
Color, True							
Color, True	36.6		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	115	BL:INT		%		03-OCT-18	
TDS (Calculated)	193			mg/L		03-OCT-18	
Hardness (as CaCO3)	176			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	8.14		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	316		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	188		5.0	mg/L		15-SEP-18	R4216885

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-3 OUTLET							
Sampled By: CLIENT on 13-SEP-18 @ 11:45							
Matrix: SW							
pH, Conductivity and Alkalinity (T & P)							
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	154		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	4.34		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							
Sulfate (SO4)	18.7		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							
Total Kjeldahl Nitrogen	0.60		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0106		0.0010	mg/L		18-SEP-18	R4220108
Total P in Water by Colour							
Phosphorus (P)-Total	0.0154		0.0010	mg/L		18-SEP-18	R4220108
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		26-SEP-18	R4251208
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	49.5		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	0.048		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	12.7		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	<0.0050		0.0050	mg/L		03-OCT-18	R4258599
Potassium (K)-Dissolved	2.12		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	13.3		1.0	mg/L		03-OCT-18	R4258599
Total Metals							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0698		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	0.00037		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Total	0.0422		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Total	0.075		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	0.000011		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	0.00026		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	0.00022		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	0.00050		0.00050	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-3 OUTLET							
Sampled By: CLIENT on 13-SEP-18 @ 11:45							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Lead (Pb)-Total	0.000089		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	0.0101		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	0.000342		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	0.00111		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	<0.050		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	0.00168		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	0.000052		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	3.65		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Total	0.126		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	7.15		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	0.00189		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	0.000243		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	0.000295		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	45.2		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	0.310		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	11.8		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	0.0593		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	2.04		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	12.9		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	17.3		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	<0.10		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	0.0018		0.0010	mg/L		21-SEP-18	R4231049
Boron (B)-Total	0.0751		0.0020	mg/L		02-OCT-18	R4258478
Total Dissolved Solids	172		12	mg/L		19-SEP-18	R4227997
Mercury (Hg)-Total	0.00098		0.00050	ug/L		21-SEP-18	R4232461
Total Organic Carbon	17.5		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	8.7		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-OCT-18	R4254492
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-OCT-18	02-OCT-18	R4257841
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	0.0686		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	0.0012	RRV	0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	0.00037		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	0.0409		0.00010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-3 OUTLET							
Sampled By: CLIENT on 13-SEP-18 @ 11:45							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	0.069		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	41.4		0.50	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	0.00034		0.00020	mg/L		02-OCT-18	R4258478
Iron (Fe)-Dissolved	0.046		0.010	mg/L		02-OCT-18	R4258478
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	12.2		0.10	mg/L		02-OCT-18	R4258478
Manganese (Mn)-Dissolved	0.00098		0.00010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	0.000329		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	0.00090		0.00050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	2.01		0.50	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	0.000059		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	3.54		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	12.7		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	0.127		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	0.000213		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
L2164033-4 DUPLICATE							
Sampled By: CLIENT on 13-SEP-18 @ 13:00							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	3.55		0.10	ug/L	14-SEP-18	14-SEP-18	R4254067
GROUP 1 - RAMP							
Color, True							
Color, True	37.0		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	114	BL:INT		%		03-OCT-18	
TDS (Calculated)	192			mg/L		03-OCT-18	
Hardness (as CaCO3)	174			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	8.13		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	317		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	188		5.0	mg/L		15-SEP-18	R4216885
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	154		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	4.36		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-4 DUPLICATE							
Sampled By: CLIENT on 13-SEP-18 @ 13:00							
Matrix: SW							
Sulfate in Water by IC							
Sulfate (SO4)	18.8		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							
Total Kjeldahl Nitrogen	0.66		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	0.0089		0.0010	mg/L		18-SEP-18	R4220108
Total P in Water by Colour							
Phosphorus (P)-Total	0.0184		0.0010	mg/L		18-SEP-18	R4220108
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		26-SEP-18	R4251208
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	49.0		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	0.042		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	12.6		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	<0.0050		0.0050	mg/L		03-OCT-18	R4258599
Potassium (K)-Dissolved	2.12		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	13.2		1.0	mg/L		03-OCT-18	R4258599
Total Metals							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	0.0714		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	0.00035		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Total	0.0419		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	0.000013		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	0.00025		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	0.00020		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Lead (Pb)-Total	0.000096		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	0.0101		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	0.000361		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	0.00108		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	<0.050		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	0.00157		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	3.66		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-4 DUPLICATE							
Sampled By: CLIENT on 13-SEP-18 @ 13:00							
Matrix: SW							
Total Metals in Water by CRC ICPMS							
Strontium (Sr)-Total	0.129		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	7.18		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	0.00192		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	0.000224		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	0.00051		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	0.000313		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	45.3		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	0.313		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	11.7		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	0.0593		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	2.05		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	12.9		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	17.7		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	0.29		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	0.0012		0.0010	mg/L		21-SEP-18	R4231049
Boron (B)-Total	0.0749		0.0020	mg/L		02-OCT-18	R4258478
Total Dissolved Solids	184		12	mg/L		19-SEP-18	R4227997
Mercury (Hg)-Total	0.00094		0.00050	ug/L		21-SEP-18	R4232461
Total Organic Carbon	17.3		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	10.4		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-OCT-18	R4254492
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-OCT-18	02-OCT-18	R4257841
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	0.0685		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	0.0012	RRV	0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	0.00034		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	0.0402		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	0.069		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	41.6		0.50	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	0.00036		0.00020	mg/L		02-OCT-18	R4258478
Iron (Fe)-Dissolved	0.042		0.010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-4 DUPLICATE							
Sampled By: CLIENT on 13-SEP-18 @ 13:00							
Matrix: SW							
Dissolved Metals in Water by CRC ICPMS							
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	12.3		0.10	mg/L		02-OCT-18	R4258478
Manganese (Mn)-Dissolved	0.00073		0.00010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	0.000337		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	0.00087		0.00050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	2.01		0.50	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	0.000058		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	3.54		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	12.7		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	0.129		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	0.000215		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
L2164033-5 TB (TRIP BLANK)							
Sampled By: CLIENT on 13-SEP-18 @ 12:00							
Matrix: SW							
GROUP 1 - RAMP							
Color, True							
Color, True	<2.0		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	Low TDS			%		03-OCT-18	
TDS (Calculated)	<1.0			mg/L		03-OCT-18	
Hardness (as CaCO3)	<1.0			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	5.23		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	<2.0		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	<0.50		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							
Sulfate (SO4)	<0.30		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-5 TB (TRIP BLANK)							
Sampled By: CLIENT on 13-SEP-18 @ 12:00							
Matrix: SW							
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	<0.0010		0.0010	mg/L		15-SEP-18	R4217003
Total P in Water by Colour							
Phosphorus (P)-Total	<0.0010		0.0010	mg/L		15-SEP-18	R4217003
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		26-SEP-18	R4251208
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	<0.10		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	<0.030		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	<0.10		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	<0.0050		0.0050	mg/L		03-OCT-18	R4258599
Potassium (K)-Dissolved	<0.50		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	<1.0		1.0	mg/L		03-OCT-18	R4258599
Total Metals							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Lead (Pb)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	<0.050		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	<0.10		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	<0.50		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	<0.000060		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-5 TB (TRIP BLANK)							
Sampled By: CLIENT on 13-SEP-18 @ 12:00							
Matrix: SW							
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	<0.10		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	<0.030		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	<0.10		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	<0.0050		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	<0.50		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	<1.0		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	<0.50		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	<0.10		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	<0.0010		0.0010	mg/L		01-OCT-18	R4256907
Boron (B)-Total	<0.0020		0.0020	mg/L		02-OCT-18	R4258478
Total Dissolved Solids	<12		12	mg/L		19-SEP-18	R4227997
Total Organic Carbon	<0.50		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	<3.0		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	<0.0020		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	0.0012	RRV	0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	<0.010		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	<0.50		0.50	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		02-OCT-18	R4258478
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	<0.10		0.10	mg/L		02-OCT-18	R4258478
Manganese (Mn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	<0.50		0.50	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	<0.050		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	<1.0		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-5 TB (TRIP BLANK)							
Sampled By: CLIENT on 13-SEP-18 @ 12:00							
Matrix: SW							
L2164033-6 FIELD BLANK							
Sampled By: CLIENT on 13-SEP-18							
Matrix: SW							
Chlorophyll a							
Chlorophyll a by fluorometry							
Chlorophyll a	<0.10		0.10	ug/L	14-SEP-18	14-SEP-18	R4254067
GROUP 1 - RAMP							
Color, True							
Color, True	<2.0		2.0	C.U.		14-SEP-18	R4216326
Ion Balance Calculation							
Ion Balance	Low TDS			%		03-OCT-18	
TDS (Calculated)	<1.0			mg/L		03-OCT-18	
Hardness (as CaCO3)	<1.0			mg/L		03-OCT-18	
pH, Conductivity and Alkalinity (T & P)							
pH	5.23		0.10	pH		15-SEP-18	R4216885
Conductivity (EC)	<2.0		2.0	uS/cm		15-SEP-18	R4216885
Bicarbonate Alkalinity (as HCO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Carbonate Alkalinity (as CO3)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Hydroxide Alkalinity (as OH)	<5.0		5.0	mg/L		15-SEP-18	R4216885
Alkalinity, Phenolphthalein (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
Alkalinity, Total (as CaCO3)	<2.0		2.0	mg/L		15-SEP-18	R4216885
GROUP 2 - RAMP							
Chloride in Water by IC							
Chloride (Cl)	<0.50		0.50	mg/L		14-SEP-18	R4216859
Sulfate in Water by IC							
Sulfate (SO4)	<0.30		0.30	mg/L		14-SEP-18	R4216859
Sulphide							
Sulphide (as S)	<0.0015		0.0015	mg/L		19-SEP-18	R4228788
GROUP 3 - RAMP							
Ammonia in Water by Colour							
Ammonia, Total (as N)	<0.050		0.050	mg/L		14-SEP-18	R4216414
Nitrate in Water by IC							
Nitrate (as N)	<0.020		0.020	mg/L		14-SEP-18	R4216859
Nitrate+Nitrite							
Nitrate and Nitrite (as N)	<0.022		0.022	mg/L		17-SEP-18	
Nitrite in Water by IC							
Nitrite (as N)	<0.010		0.010	mg/L		14-SEP-18	R4216859
TKN in Water by Colour							
Total Kjeldahl Nitrogen	<0.20		0.20	mg/L	03-OCT-18	04-OCT-18	R4259914
Total Dissolved P in Water by Colour							
Phosphorus (P)-Total Dissolved	<0.0010		0.0010	mg/L		18-SEP-18	R4220108
Total P in Water by Colour							
Phosphorus (P)-Total	<0.0010		0.0010	mg/L		18-SEP-18	R4220108
GROUP 5 - RAMP HATFIELD							
Hydrocarbons,Rec. (I.R.)							
Hydrocarbons, Recoverable (I.R.)	<1.0		1.0	mg/L		26-SEP-18	R4251208
Dissolved Metals							
Dissolved Metals by ICPOES							
Dissolved Metals Filtration Location	LAB					03-OCT-18	R4258574
Calcium (Ca)-Dissolved	<0.10		0.10	mg/L		03-OCT-18	R4258599
Iron (Fe)-Dissolved	<0.030		0.030	mg/L		03-OCT-18	R4258599
Magnesium (Mg)-Dissolved	<0.10		0.10	mg/L		03-OCT-18	R4258599
Manganese (Mn)-Dissolved	<0.0050		0.0050	mg/L		03-OCT-18	R4258599

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-6 FIELD BLANK							
Sampled By: CLIENT on 13-SEP-18							
Matrix: SW							
Dissolved Metals by ICPOES							
Potassium (K)-Dissolved	<0.50		0.50	mg/L		03-OCT-18	R4258599
Sodium (Na)-Dissolved	<1.0		1.0	mg/L		03-OCT-18	R4258599
Total Metals							
Total Metals in Water by CRC ICPMS							
Aluminum (Al)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Total	<0.010		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Total	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Cesium (Cs)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Lead (Pb)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Lithium (Li)-Total	<0.0010		0.0010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Phosphorus (P)-Total	<0.050		0.050	mg/L		02-OCT-18	R4258478
Rubidium (Rb)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Selenium (Se)-Total	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Total	<0.10		0.10	mg/L		02-OCT-18	R4258478
Silver (Ag)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Sulfur (S)-Total	<0.50		0.50	mg/L		02-OCT-18	R4258478
Tellurium (Te)-Total	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Thorium (Th)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Total	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Tungsten (W)-Total	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Uranium (U)-Total	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Total	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Total	<0.0030		0.0030	mg/L		02-OCT-18	R4258478
Zirconium (Zr)-Total	<0.000060		0.000060	mg/L		02-OCT-18	R4258478
Total Metals in Water by ICPOES							
Calcium (Ca)-Total	<0.10		0.10	mg/L		02-OCT-18	R4257716
Iron (Fe)-Total	<0.030		0.030	mg/L		02-OCT-18	R4257716
Magnesium (Mg)-Total	<0.10		0.10	mg/L		02-OCT-18	R4257716
Manganese (Mn)-Total	<0.0050		0.0050	mg/L		02-OCT-18	R4257716
Potassium (K)-Total	<0.50		0.50	mg/L		02-OCT-18	R4257716
Sodium (Na)-Total	<1.0		1.0	mg/L		02-OCT-18	R4257716
Miscellaneous Parameters							
Chlorine, Total	<0.10		0.10	mg/L		14-SEP-18	R4216253
Orthophosphate-Dissolved (as P)	<0.010		0.010	mg/L		14-SEP-18	R4216405
Dissolved Organic Carbon	0.56		0.50	mg/L		18-SEP-18	R4226749
Naphthenic Acids	<0.10		0.10	mg/L	17-SEP-18	19-SEP-18	R4223648
Phenols (4AAP)	<0.0010		0.0010	mg/L		21-SEP-18	R4231049
Boron (B)-Total	<0.0020		0.0020	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2164033-6 FIELD BLANK							
Sampled By: CLIENT on 13-SEP-18							
Matrix: SW							
Total Dissolved Solids	<12		12	mg/L		19-SEP-18	R4227997
Mercury (Hg)-Total	<0.00050		0.00050	ug/L		21-SEP-18	R4232461
Total Organic Carbon	<0.50		0.50	mg/L		18-SEP-18	R4223827
Total Suspended Solids	<3.0		3.0	mg/L	20-SEP-18	20-SEP-18	R4228387
Diss. Mercury in Water by CVAFS (Ultra)							
Dissolved Mercury Filtration Location	LAB					01-OCT-18	R4254492
Mercury (Hg)-Dissolved	<0.00050		0.00050	ug/L	01-OCT-18	02-OCT-18	R4257841
Dissolved Boron by CRC CCMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Boron (B)-Dissolved	<0.0020		0.0020	mg/L		02-OCT-18	R4258478
Dissolved Metals in Water by CRC ICPMS							
Dissolved Metals Filtration Location	LAB					02-OCT-18	R4258229
Aluminum (Al)-Dissolved	<0.0010	RRV	0.0010	mg/L		02-OCT-18	R4258478
Antimony (Sb)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Arsenic (As)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Barium (Ba)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Beryllium (Be)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Bismuth (Bi)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Boron (B)-Dissolved	<0.010		0.010	mg/L		02-OCT-18	R4258478
Cadmium (Cd)-Dissolved	<0.0000050		0.0000050	mg/L		02-OCT-18	R4258478
Calcium (Ca)-Dissolved	<0.50		0.50	mg/L		02-OCT-18	R4258478
Chromium (Cr)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Cobalt (Co)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Copper (Cu)-Dissolved	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Iron (Fe)-Dissolved	<0.010		0.010	mg/L		02-OCT-18	R4258478
Lead (Pb)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Magnesium (Mg)-Dissolved	<0.10		0.10	mg/L		02-OCT-18	R4258478
Manganese (Mn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Molybdenum (Mo)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Nickel (Ni)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Potassium (K)-Dissolved	<0.50		0.50	mg/L		02-OCT-18	R4258478
Selenium (Se)-Dissolved	<0.000050		0.000050	mg/L		02-OCT-18	R4258478
Silicon (Si)-Dissolved	<0.050		0.050	mg/L		02-OCT-18	R4258478
Silver (Ag)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Sodium (Na)-Dissolved	<1.0		1.0	mg/L		02-OCT-18	R4258478
Strontium (Sr)-Dissolved	<0.00020		0.00020	mg/L		02-OCT-18	R4258478
Thallium (Tl)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Tin (Sn)-Dissolved	<0.00010		0.00010	mg/L		02-OCT-18	R4258478
Titanium (Ti)-Dissolved	<0.00030		0.00030	mg/L		02-OCT-18	R4258478
Uranium (U)-Dissolved	<0.000010		0.000010	mg/L		02-OCT-18	R4258478
Vanadium (V)-Dissolved	<0.00050		0.00050	mg/L		02-OCT-18	R4258478
Zinc (Zn)-Dissolved	<0.0010		0.0010	mg/L		02-OCT-18	R4258478

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
BL:INT	Balance Reviewed: Interference Or Non-Measured Component
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
B-D-L-CCMS-CL	Water	Dissolved Boron by CRC CCMS	APHA 3030B/6020A (mod)

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procudure involves filtration (APHA 3030B&E), then instrumental analysis is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

B-T-L-CCMS-CL | Water | Total B (Low) in Water by CRC ICPMS | EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

C-DOC-HTC-WP | Water | Dissolved Organic Carbon by Combustion | APHA 5310 B-WP

Filtered (0.45 um) sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

C-TOC-HTC-WP | Water | Total Organic Carbon by Combustion | APHA 5310 B-WP

Sample is acidified and purged to remove inorganic carbon, then injected into a heated reaction chamber where organic carbon is oxidized to CO2 which is then transported in the carrier gas stream and measured via a non-dispersive infrared analyzer.

CHL/A-ACET-FLUORO-WP | Water | Chlorophyll a by fluorometry | EPA 445.0 ACET

This analysis is done using procedures modified from EPA method 445.0. Chlorophyll a is determined by a 90 % acetone extraction followed with analysis by fluorometry using the non-acidification procedure. This method is not subject to interferences from chlorophyll b.

CL-IC-N-ED | Water | Chloride in Water by IC | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CL2-TOT-ED | Water | Chlorine, Total | APHA 4500 Cl G-Colorimetry

Chlorine (residual), as free or total, is analyzed using the DPD colourimetric method. The recommended hold time for these tests is 15 minutes; field testing is recommended for best results. Chlorine can be rapidly consumed by organic matter, if present, and dissipates rapidly into headspace.

COL-TRU-ED | Water | Color, True | APHA 2120

True Colour is measured using a colorimeter by comparison to platinum-cobalt standards using the single wavelength method (450 - 465 nm) after filtration of sample through a 0.45 um filter. Colour measurements can be highly pH dependent, and apply to the pH of the sample as received (at time of testing), without pH adjustment. Concurrent measurement of sample pH is recommended.

HG-D-U-CVAF-VA | Water | Diss. Mercury in Water by CVAFS (Ultra) | APHA 3030 B / EPA 1631 REV. E

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure may involve preliminary sample treatment by filtration (APHA 3030B) and involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

HG-T-U-CVAF-VA | Water | Total Mercury in Water by CVAFS (Ultra) | EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

HOG-IR-ED | Water | Hydrocarbons,Rec. (I.R.) | APHA 5520 C-Tetra Cl Ext Infrared

A water sample is acidified and then liquid-liquid extracted using tetrachloroethylene solvent, followed by filtration of the decanted solvent into a volumetric flask. The extract is treated with silica gel to remove polar, naturally-occurring hydrocarbons, to yield mineral oil and grease. Finally, the extract is brought to a discrete final volume and analysed by infrared spectrophotometry. The absorbance of the carbon-hydrogen bond in the infrared is used to measure oil and grease. Spectra are collected in transmission mode using a glass cuvette.

IONBALANCE-ED | Water | Ion Balance Calculation | APHA 1030E

MET-D-CCMS-CL | Water | Dissolved Metals in Water by CRC ICPMS | APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-DIS-ICP-CL	Water	Dissolved Metals by ICPOES	APHA 3030B/EPA 6010B

"This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (APHA Method 3030B) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-CL	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-TOT-ICP-CL	Water	Total Metals in Water by ICPOES	EPA 200.2/6010B

Water samples are digested with nitric and hydrochloric acids, and analyzed by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B). Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NAPHTHENIC ACID-L-FM	Water	Naphthenic Acids by FTIR (Low Level)	Naphthenic Acids by FTIR,Syncrude,1994

Dissolved naphthenic acids are solvent extracted from acidified aqueous samples using Dichloromethane prior to quantitation by Fourier Transform Infra-Red spectroscopy. Note that FTIR is not uniquely selective to naphthenic acids. If present, other carboxylic acids (e.g. humic acids, fulvic acids) may also be detected by this method.

NH3-COL-ED	Water	Ammonia in Water by Colour	APHA 4500 NH3-NITROGEN (AMMONIA)

This analysis is carried out using procedures adapted from APHA Method 4500 NH3 "NITROGEN (AMMONIA)". Ammonia is determined using the automated phenate colourimetric method.

NO2+NO3-CALC-ED	Water	Nitrate+Nitrite	CALCULATION
NO2-IC-N-ED	Water	Nitrite in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-IC-N-ED	Water	Nitrate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-L-COL-ED	Water	Total P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.

P-TD-L-COL-ED	Water	Total Dissolved P in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorous is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.

PH/EC/ALKS-ED	Water	pH, Conductivity and Alkalinity (T & P)	APHA 4500-H, 2510, 2320

All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PHENOLS-4AAP-WT	Water	Phenol (4AAP)	EPA 9066

An automated method is used to distill the sample. The distillate is then buffered to pH 9.4 which reacts with 4AAP and potassium ferricyanide to form a red complex which is measured colorimetrically.

PO4-DO-COL-ED	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P PHOSPHORUS

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.

SO4-IC-N-ED	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-FM	Water	Total Dissolved Solids (TDS)	APHA 2540 C

Gravimetric determination of solids in waters by filtration and evaporating filtrate to dryness at 180 degrees Celsius.

SOLIDS-TOTSUS-FM	Water	Total Suspended Solids (TSS)	APHA 2540 D

Gravimetric determination of solids in waters by filtration and drying filter at 104 degrees Celsius.

SULPHIDE-CFA-ED	Water	Sulphide	APHA 4500 -S E-Auto-Colorimetry

A continuous flow manifold adds HCl to the sample which converts sulphide to a gas, then the sulphide is separated from the flow using a gas dialysis membrane. A colorimetric reaction produces a methylene blue compound which is measured at 660 nm. This follows the Standard Methods procedure

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
4500 S-E.			
TKN-CFA-ED	Water	TKN in Water by Colour	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg "Nitrogen (Organic)". Total Kjeldahl Nitrogen is determined by sample digestion at 380 celcius with analysis using an automated colourimetric finish.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
FM	ALS ENVIRONMENTAL - FORT MCMURRAY, ALBERTA, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
WT	ALS ENVIRONMENTAL - WATERLOO, ONTARIO, CANADA
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Workorder: L2164033 Report Date: 11-DEC-18

Client: Hatfield Consultants
200-580 Harbourside Drive
North Vancouver BC V7P 0A3
Contact: Chris Jaeggle

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
B-D-L-CCMS-CL	Water							
Batch R4258478								
WG2893782-3 DUP		**L2164033-1**						
Boron (B)-Dissolved		0.0670	0.0685		mg/L	2.3	20	02-OCT-18
WG2893782-10 LCS		**TMRM**						
Boron (B)-Dissolved			102.7		%		80-120	02-OCT-18
WG2893782-14 LCS		**TMRM**						
Boron (B)-Dissolved			94.4		%		80-120	02-OCT-18
WG2893782-2 LCS		**TMRM**						
Boron (B)-Dissolved			98.7		%		80-120	02-OCT-18
WG2893782-6 LCS		**TMRM**						
Boron (B)-Dissolved			103.1		%		80-120	02-OCT-18
WG2893782-1 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	02-OCT-18
WG2893782-13 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	02-OCT-18
WG2893782-5 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	02-OCT-18
WG2893782-9 MB								
Boron (B)-Dissolved			<0.0020		mg/L		0.002	02-OCT-18
WG2893782-4 MS		**L2164033-6**						
Boron (B)-Dissolved			107.2		%		70-130	02-OCT-18
B-T-L-CCMS-CL	Water							
Batch R4253268								
WG2891783-2 LCS		**TMRM**						
Boron (B)-Total			115.4		%		80-120	01-OCT-18
WG2891783-1 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	01-OCT-18
Batch R4256952								
WG2891783-5 LCS		**TMRM**						
Boron (B)-Total			84.3		%		80-120	01-OCT-18
WG2891783-4 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	01-OCT-18
Batch R4258478								
WG2891783-6 DUP		**L2164033-1**						
Boron (B)-Total		0.0747	0.0758		mg/L	1.4	20	02-OCT-18
WG2891783-8 LCS		**TMRM**						
Boron (B)-Total			98.9		%		80-120	02-OCT-18
WG2891783-7 MB								
Boron (B)-Total			<0.0020		mg/L		0.002	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-DOC-HTC-WP	Water							
Batch R4226749								
WG2880480-2 LCS								
Dissolved Organic Carbon			101.8		%		80-120	18-SEP-18
WG2880480-1 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	18-SEP-18
C-TOC-HTC-WP	Water							
Batch R4223827								
WG2880525-2 LCS								
Total Organic Carbon			105.3		%		80-120	18-SEP-18
WG2880525-1 MB								
Total Organic Carbon			<0.50		mg/L		0.5	18-SEP-18
CHL/A-ACET-FLUORO-WP	Water							
Batch R4254067								
WG2891755-8 DUP		**L2164033-4**						
Chlorophyll a		3.55	3.60		ug/L	1.4	35	14-SEP-18
WG2891755-9 LCS								
Chlorophyll a			97.8		%		80-120	01-OCT-18
WG2891755-1 MB								
Chlorophyll a			<0.10		ug/L		0.1	24-SEP-18
WG2891755-2 MB								
Chlorophyll a			<0.10		ug/L		0.1	25-SEP-18
WG2891755-3 MB								
Chlorophyll a			<0.10		ug/L		0.1	26-SEP-18
WG2891755-4 MB								
Chlorophyll a			<0.10		ug/L		0.1	14-SEP-18
CL-IC-N-ED	Water							
Batch R4216859								
WG2875838-11 LCS								
Chloride (Cl)			101.3		%		90-110	13-SEP-18
WG2875838-13 LCS								
Chloride (Cl)			102.7		%		90-110	14-SEP-18
WG2875838-15 LCS								
Chloride (Cl)			101.5		%		90-110	14-SEP-18
WG2875838-2 LCS								
Chloride (Cl)			101.3		%		90-110	13-SEP-18
WG2875838-1 MB								
Chloride (Cl)			<0.50		mg/L		0.5	13-SEP-18
WG2875838-12 MB								
Chloride (Cl)			<0.50		mg/L		0.5	13-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-IC-N-ED	Water							
Batch R4216859								
WG2875838-14 MB								
Chloride (Cl)			<0.50		mg/L		0.5	14-SEP-18
WG2875838-16 MB								
Chloride (Cl)			<0.50		mg/L		0.5	14-SEP-18
CL2-TOT-ED	Water							
Batch R4216253								
WG2876840-3 DUP		**L2164033-4**						
Chlorine, Total		<0.10	<0.10	RPD-NA	mg/L	N/A	15	14-SEP-18
WG2876840-2 LCS								
Chlorine, Total			106.0		%		75-125	14-SEP-18
WG2876840-1 MB								
Chlorine, Total			<0.10		mg/L		0.1	14-SEP-18
COL-TRU-ED	Water							
Batch R4216326								
WG2876948-3 DUP		**L2164033-2**						
Color, True		131	130		C.U.	0.1	20	14-SEP-18
WG2876948-2 LCS								
Color, True			96.3		%		85-115	14-SEP-18
WG2876948-1 MB								
Color, True			<2.0		C.U.		2	14-SEP-18
HG-D-U-CVAF-VA	Water							
Batch R4257841								
WG2891978-3 DUP		**L2164033-2**						
Mercury (Hg)-Dissolved		0.00070	0.00078		ug/L	11	20	02-OCT-18
WG2891978-2 LCS								
Mercury (Hg)-Dissolved			99.4		%		80-120	02-OCT-18
WG2892801-2 LCS								
Mercury (Hg)-Dissolved			99.4		%		80-120	02-OCT-18
WG2891978-1 MB		**LF**						
Mercury (Hg)-Dissolved			<0.00050		ug/L		0.0005	02-OCT-18
WG2892801-1 MB								
Mercury (Hg)-Dissolved			<0.00050		ug/L		0.0005	02-OCT-18
WG2891978-4 MS		**L2164033-1**						
Mercury (Hg)-Dissolved			98.0		%		70-130	02-OCT-18
HG-T-U-CVAF-VA	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-T-U-CVAF-VA	Water							
Batch R4232461								
WG2883167-2 LCS								
Mercury (Hg)-Total			94.3		%		80-120	21-SEP-18
WG2883167-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	21-SEP-18
HOG-IR-ED	Water							
Batch R4242690								
WG2886304-2 LCS								
Hydrocarbons, Recoverable (I.R.)			95.0		%		70-130	25-SEP-18
WG2886304-1 MB								
Hydrocarbons, Recoverable (I.R.)			<1.0		mg/L		1	25-SEP-18
Batch R4251208								
WG2887386-2 LCS								
Hydrocarbons, Recoverable (I.R.)			96.2		%		70-130	26-SEP-18
WG2887386-1 MB								
Hydrocarbons, Recoverable (I.R.)			<1.0		mg/L		1	26-SEP-18
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-3 DUP		**L2164033-1**						
Aluminum (Al)-Dissolved		<0.0010	0.0010	RPD-NA	mg/L	N/A	20	02-OCT-18
Antimony (Sb)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Arsenic (As)-Dissolved		0.00036	0.00036		mg/L	0.1	20	02-OCT-18
Barium (Ba)-Dissolved		0.0406	0.0409		mg/L	0.9	20	02-OCT-18
Beryllium (Be)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Bismuth (Bi)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Boron (B)-Dissolved		0.067	0.069		mg/L	2.3	20	02-OCT-18
Cadmium (Cd)-Dissolved		<0.0000050	<0.0000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Calcium (Ca)-Dissolved		40.5	40.9		mg/L	0.9	20	02-OCT-18
Cesium (Cs)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Chromium (Cr)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Cobalt (Co)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Copper (Cu)-Dissolved		0.00031	0.00029		mg/L	8.4	20	02-OCT-18
Lead (Pb)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Lithium (Li)-Dissolved		0.0083	0.0085		mg/L	1.5	20	02-OCT-18
Magnesium (Mg)-Dissolved		12.5	12.6		mg/L	0.8	20	02-OCT-18
Molybdenum (Mo)-Dissolved		0.000337	0.000354		mg/L	4.9	20	02-OCT-18
Nickel (Ni)-Dissolved		0.00090	0.00089		mg/L	1.7	20	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-3 DUP		**L2164033-1**						
Phosphorus (P)-Dissolved		<0.050	<0.050	RPD-NA	mg/L	N/A	20	02-OCT-18
Potassium (K)-Dissolved		1.97	1.99		mg/L	0.9	20	02-OCT-18
Rubidium (Rb)-Dissolved		0.00144	0.00149		mg/L	3.4	20	02-OCT-18
Selenium (Se)-Dissolved		0.000058	0.000057		mg/L	1.9	20	02-OCT-18
Silicon (Si)-Dissolved		3.56	3.59		mg/L	1.0	20	02-OCT-18
Silver (Ag)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Sodium (Na)-Dissolved		12.6	12.9		mg/L	1.7	20	02-OCT-18
Strontium (Sr)-Dissolved		0.124	0.129		mg/L	4.3	20	02-OCT-18
Sulfur (S)-Dissolved		7.47	7.51		mg/L	0.5	20	02-OCT-18
Tellurium (Te)-Dissolved		<0.00020	<0.00020	RPD-NA	mg/L	N/A	20	02-OCT-18
Thallium (Tl)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Thorium (Th)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Tin (Sn)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Titanium (Ti)-Dissolved		<0.00030	<0.00030	RPD-NA	mg/L	N/A	20	02-OCT-18
Tungsten (W)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Uranium (U)-Dissolved		0.000212	0.000217		mg/L	2.3	20	02-OCT-18
Vanadium (V)-Dissolved		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	02-OCT-18
Zinc (Zn)-Dissolved		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	02-OCT-18
Zirconium (Zr)-Dissolved		0.000181	0.000201		mg/L	10	20	02-OCT-18
WG2893782-10 LCS		**TMRM**						
Aluminum (Al)-Dissolved			113.5		%		80-120	02-OCT-18
Antimony (Sb)-Dissolved			104.0		%		80-120	02-OCT-18
Arsenic (As)-Dissolved			104.3		%		80-120	02-OCT-18
Barium (Ba)-Dissolved			108.0		%		80-120	02-OCT-18
Beryllium (Be)-Dissolved			106.2		%		80-120	02-OCT-18
Bismuth (Bi)-Dissolved			104.2		%		80-120	02-OCT-18
Boron (B)-Dissolved			102.7		%		80-120	02-OCT-18
Cadmium (Cd)-Dissolved			103.7		%		80-120	02-OCT-18
Calcium (Ca)-Dissolved			108.1		%		80-120	02-OCT-18
Cesium (Cs)-Dissolved			105.0		%		80-120	02-OCT-18
Chromium (Cr)-Dissolved			109.9		%		80-120	02-OCT-18
Cobalt (Co)-Dissolved			108.5		%		80-120	02-OCT-18
Copper (Cu)-Dissolved			105.4		%		80-120	02-OCT-18
Iron (Fe)-Dissolved			110.2		%		80-120	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-10 LCS		**TMRM**						
Lead (Pb)-Dissolved			106.5		%		80-120	02-OCT-18
Lithium (Li)-Dissolved			107.8		%		80-120	02-OCT-18
Magnesium (Mg)-Dissolved			114.1		%		80-120	02-OCT-18
Manganese (Mn)-Dissolved			110.1		%		80-120	02-OCT-18
Molybdenum (Mo)-Dissolved			107.6		%		80-120	02-OCT-18
Nickel (Ni)-Dissolved			105.8		%		80-120	02-OCT-18
Phosphorus (P)-Dissolved			106.9		%		70-130	02-OCT-18
Potassium (K)-Dissolved			109.6		%		80-120	02-OCT-18
Rubidium (Rb)-Dissolved			103.9		%		80-120	02-OCT-18
Selenium (Se)-Dissolved			99.0		%		80-120	02-OCT-18
Silicon (Si)-Dissolved			108.5		%		60-140	02-OCT-18
Silver (Ag)-Dissolved			105.2		%		80-120	02-OCT-18
Sodium (Na)-Dissolved			112.4		%		80-120	02-OCT-18
Strontium (Sr)-Dissolved			110.4		%		80-120	02-OCT-18
Sulfur (S)-Dissolved			104.4		%		80-120	02-OCT-18
Tellurium (Te)-Dissolved			96.3		%		80-120	02-OCT-18
Thallium (Tl)-Dissolved			105.7		%		80-120	02-OCT-18
Thorium (Th)-Dissolved			104.1		%		80-120	02-OCT-18
Tin (Sn)-Dissolved			105.4		%		80-120	02-OCT-18
Titanium (Ti)-Dissolved			101.6		%		80-120	02-OCT-18
Tungsten (W)-Dissolved			104.7		%		80-120	02-OCT-18
Uranium (U)-Dissolved			111.4		%		80-120	02-OCT-18
Vanadium (V)-Dissolved			109.9		%		80-120	02-OCT-18
Zinc (Zn)-Dissolved			107.0		%		80-120	02-OCT-18
Zirconium (Zr)-Dissolved			107.2		%		80-120	02-OCT-18
WG2893782-14 LCS		**TMRM**						
Aluminum (Al)-Dissolved			105.9		%		80-120	02-OCT-18
Antimony (Sb)-Dissolved			105.1		%		80-120	02-OCT-18
Arsenic (As)-Dissolved			101.3		%		80-120	02-OCT-18
Barium (Ba)-Dissolved			104.8		%		80-120	02-OCT-18
Beryllium (Be)-Dissolved			98.5		%		80-120	02-OCT-18
Bismuth (Bi)-Dissolved			103.8		%		80-120	02-OCT-18
Boron (B)-Dissolved			94.4		%		80-120	02-OCT-18
Cadmium (Cd)-Dissolved			100.2		%		80-120	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-14 LCS		**TMRM**						
Calcium (Ca)-Dissolved			98.1		%		80-120	02-OCT-18
Cesium (Cs)-Dissolved			101.3		%		80-120	02-OCT-18
Chromium (Cr)-Dissolved			104.9		%		80-120	02-OCT-18
Cobalt (Co)-Dissolved			102.8		%		80-120	02-OCT-18
Copper (Cu)-Dissolved			101.0		%		80-120	02-OCT-18
Iron (Fe)-Dissolved			104.9		%		80-120	02-OCT-18
Lead (Pb)-Dissolved			103.3		%		80-120	02-OCT-18
Lithium (Li)-Dissolved			95.2		%		80-120	02-OCT-18
Magnesium (Mg)-Dissolved			108.6		%		80-120	02-OCT-18
Manganese (Mn)-Dissolved			103.2		%		80-120	02-OCT-18
Molybdenum (Mo)-Dissolved			107.2		%		80-120	02-OCT-18
Nickel (Ni)-Dissolved			101.6		%		80-120	02-OCT-18
Phosphorus (P)-Dissolved			107.3		%		70-130	02-OCT-18
Potassium (K)-Dissolved			105.2		%		80-120	02-OCT-18
Rubidium (Rb)-Dissolved			100.3		%		80-120	02-OCT-18
Selenium (Se)-Dissolved			99.2		%		80-120	02-OCT-18
Silicon (Si)-Dissolved			104.3		%		60-140	02-OCT-18
Silver (Ag)-Dissolved			102.5		%		80-120	02-OCT-18
Sodium (Na)-Dissolved			107.6		%		80-120	02-OCT-18
Strontium (Sr)-Dissolved			108.0		%		80-120	02-OCT-18
Sulfur (S)-Dissolved			99.1		%		80-120	02-OCT-18
Tellurium (Te)-Dissolved			99.0		%		80-120	02-OCT-18
Thallium (Tl)-Dissolved			101.8		%		80-120	02-OCT-18
Thorium (Th)-Dissolved			102.2		%		80-120	02-OCT-18
Tin (Sn)-Dissolved			102.5		%		80-120	02-OCT-18
Titanium (Ti)-Dissolved			96.6		%		80-120	02-OCT-18
Tungsten (W)-Dissolved			102.5		%		80-120	02-OCT-18
Uranium (U)-Dissolved			105.6		%		80-120	02-OCT-18
Vanadium (V)-Dissolved			104.5		%		80-120	02-OCT-18
Zinc (Zn)-Dissolved			105.3		%		80-120	02-OCT-18
Zirconium (Zr)-Dissolved			105.9		%		80-120	02-OCT-18
WG2893782-2 LCS		**TMRM**						
Aluminum (Al)-Dissolved			103.9		%		80-120	02-OCT-18
Antimony (Sb)-Dissolved			99.3		%		80-120	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch **R4258478**								
WG2893782-2 **LCS**		**TMRM**						
Arsenic (As)-Dissolved			97.9		%		80-120	02-OCT-18
Barium (Ba)-Dissolved			103.4		%		80-120	02-OCT-18
Beryllium (Be)-Dissolved			94.8		%		80-120	02-OCT-18
Bismuth (Bi)-Dissolved			98.4		%		80-120	02-OCT-18
Boron (B)-Dissolved			98.7		%		80-120	02-OCT-18
Cadmium (Cd)-Dissolved			99.4		%		80-120	02-OCT-18
Calcium (Ca)-Dissolved			98.5		%		80-120	02-OCT-18
Cesium (Cs)-Dissolved			98.7		%		80-120	02-OCT-18
Chromium (Cr)-Dissolved			103.6		%		80-120	02-OCT-18
Cobalt (Co)-Dissolved			102.9		%		80-120	02-OCT-18
Copper (Cu)-Dissolved			101.2		%		80-120	02-OCT-18
Iron (Fe)-Dissolved			106.1		%		80-120	02-OCT-18
Lead (Pb)-Dissolved			99.9		%		80-120	02-OCT-18
Lithium (Li)-Dissolved			96.2		%		80-120	02-OCT-18
Magnesium (Mg)-Dissolved			104.0		%		80-120	02-OCT-18
Manganese (Mn)-Dissolved			103.0		%		80-120	02-OCT-18
Molybdenum (Mo)-Dissolved			103.3		%		80-120	02-OCT-18
Nickel (Ni)-Dissolved			100.8		%		80-120	02-OCT-18
Phosphorus (P)-Dissolved			102.5		%		70-130	02-OCT-18
Potassium (K)-Dissolved			104.4		%		80-120	02-OCT-18
Rubidium (Rb)-Dissolved			105.7		%		80-120	02-OCT-18
Selenium (Se)-Dissolved			95.8		%		80-120	02-OCT-18
Silicon (Si)-Dissolved			102.5		%		60-140	02-OCT-18
Silver (Ag)-Dissolved			98.4		%		80-120	02-OCT-18
Sodium (Na)-Dissolved			103.7		%		80-120	02-OCT-18
Strontium (Sr)-Dissolved			102.6		%		80-120	02-OCT-18
Sulfur (S)-Dissolved			95.5		%		80-120	02-OCT-18
Tellurium (Te)-Dissolved			91.4		%		80-120	02-OCT-18
Thallium (Tl)-Dissolved			96.6		%		80-120	02-OCT-18
Thorium (Th)-Dissolved			98.3		%		80-120	02-OCT-18
Tin (Sn)-Dissolved			100.2		%		80-120	02-OCT-18
Titanium (Ti)-Dissolved			103.8		%		80-120	02-OCT-18
Tungsten (W)-Dissolved			100.7		%		80-120	02-OCT-18
Uranium (U)-Dissolved			100.3		%		80-120	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch **R4258478**								
WG2893782-2 **LCS**		**TMRM**						
Vanadium (V)-Dissolved			104.7		%		80-120	02-OCT-18
Zinc (Zn)-Dissolved			99.8		%		80-120	02-OCT-18
Zirconium (Zr)-Dissolved			101.6		%		80-120	02-OCT-18
WG2893782-6 **LCS**		**TMRM**						
Aluminum (Al)-Dissolved			105.2		%		80-120	02-OCT-18
Antimony (Sb)-Dissolved			106.9		%		80-120	02-OCT-18
Arsenic (As)-Dissolved			101.8		%		80-120	02-OCT-18
Barium (Ba)-Dissolved			108.1		%		80-120	02-OCT-18
Beryllium (Be)-Dissolved			101.3		%		80-120	02-OCT-18
Bismuth (Bi)-Dissolved			104.2		%		80-120	02-OCT-18
Boron (B)-Dissolved			103.1		%		80-120	02-OCT-18
Cadmium (Cd)-Dissolved			100.7		%		80-120	02-OCT-18
Calcium (Ca)-Dissolved			106.8		%		80-120	02-OCT-18
Cesium (Cs)-Dissolved			106.9		%		80-120	02-OCT-18
Chromium (Cr)-Dissolved			106.9		%		80-120	02-OCT-18
Cobalt (Co)-Dissolved			106.1		%		80-120	02-OCT-18
Copper (Cu)-Dissolved			103.4		%		80-120	02-OCT-18
Iron (Fe)-Dissolved			108.0		%		80-120	02-OCT-18
Lead (Pb)-Dissolved			106.1		%		80-120	02-OCT-18
Lithium (Li)-Dissolved			99.5		%		80-120	02-OCT-18
Magnesium (Mg)-Dissolved			108.5		%		80-120	02-OCT-18
Manganese (Mn)-Dissolved			105.7		%		80-120	02-OCT-18
Molybdenum (Mo)-Dissolved			113.3		%		80-120	02-OCT-18
Nickel (Ni)-Dissolved			102.5		%		80-120	02-OCT-18
Phosphorus (P)-Dissolved			102.5		%		70-130	02-OCT-18
Potassium (K)-Dissolved			105.3		%		80-120	02-OCT-18
Rubidium (Rb)-Dissolved			101.0		%		80-120	02-OCT-18
Selenium (Se)-Dissolved			97.6		%		80-120	02-OCT-18
Silicon (Si)-Dissolved			104.0		%		60-140	02-OCT-18
Silver (Ag)-Dissolved			105.2		%		80-120	02-OCT-18
Sodium (Na)-Dissolved			105.0		%		80-120	02-OCT-18
Strontium (Sr)-Dissolved			111.8		%		80-120	02-OCT-18
Sulfur (S)-Dissolved			101.2		%		80-120	02-OCT-18
Tellurium (Te)-Dissolved			97.5		%		80-120	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-6 LCS		**TMRM**						
Thallium (Tl)-Dissolved			103.7		%		80-120	02-OCT-18
Thorium (Th)-Dissolved			105.0		%		80-120	02-OCT-18
Tin (Sn)-Dissolved			105.3		%		80-120	02-OCT-18
Titanium (Ti)-Dissolved			99.6		%		80-120	02-OCT-18
Tungsten (W)-Dissolved			104.7		%		80-120	02-OCT-18
Uranium (U)-Dissolved			109.5		%		80-120	02-OCT-18
Vanadium (V)-Dissolved			107.3		%		80-120	02-OCT-18
Zinc (Zn)-Dissolved			102.9		%		80-120	02-OCT-18
Zirconium (Zr)-Dissolved			108.8		%		80-120	02-OCT-18
WG2893782-1 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Boron (B)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	02-OCT-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	02-OCT-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-1 MB								
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	02-OCT-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	02-OCT-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	02-OCT-18
WG2893782-13 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Boron (B)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	02-OCT-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	02-OCT-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-13 MB								
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	02-OCT-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	02-OCT-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	02-OCT-18
WG2893782-5 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Boron (B)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	02-OCT-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-5 MB								
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	02-OCT-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	02-OCT-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	02-OCT-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	02-OCT-18
WG2893782-9 MB								
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Barium (Ba)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Beryllium (Be)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-CL	Water							
Batch R4258478								
WG2893782-9 MB								
Boron (B)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	02-OCT-18
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Cesium (Cs)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	02-OCT-18
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	02-OCT-18
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Phosphorus (P)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Potassium (K)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Rubidium (Rb)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	02-OCT-18
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	02-OCT-18
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Sulfur (S)-Dissolved			<0.50		mg/L		0.5	02-OCT-18
Tellurium (Te)-Dissolved			<0.00020		mg/L		0.0002	02-OCT-18
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Thorium (Th)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	02-OCT-18
Tungsten (W)-Dissolved			<0.00010		mg/L		0.0001	02-OCT-18
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	02-OCT-18
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	02-OCT-18
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	02-OCT-18
Zirconium (Zr)-Dissolved			<0.000060		mg/L		0.00006	02-OCT-18
MET-DIS-ICP-CL	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DIS-ICP-CL	Water							
Batch R4258599								
WG2894220-10 LCS		**TMRM**						
Calcium (Ca)-Dissolved			102.9		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			96.1		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			100.1		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			96.9		%		80-120	03-OCT-18
Potassium (K)-Dissolved			95.4		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			97.6		%		80-120	03-OCT-18
WG2894220-13 LCS		**TMRM**						
Calcium (Ca)-Dissolved			102.6		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			94.5		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			96.9		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			96.4		%		80-120	03-OCT-18
Potassium (K)-Dissolved			94.2		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			96.4		%		80-120	03-OCT-18
WG2894220-17 LCS		**TMRM**						
Calcium (Ca)-Dissolved			105.2		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			95.7		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			98.3		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			97.0		%		80-120	03-OCT-18
Potassium (K)-Dissolved			97.8		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			98.5		%		80-120	03-OCT-18
WG2894220-2 LCS		**TMRM**						
Calcium (Ca)-Dissolved			104.1		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			97.1		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			95.5		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			98.4		%		80-120	03-OCT-18
Potassium (K)-Dissolved			97.7		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			98.0		%		80-120	03-OCT-18
WG2894220-20 LCS		**TMRM**						
Calcium (Ca)-Dissolved			104.4		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			95.6		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			101.6		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			97.1		%		80-120	03-OCT-18
Potassium (K)-Dissolved			97.8		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			99.8		%		80-120	03-OCT-18
WG2894220-24 LCS		**TMRM**						

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DIS-ICP-CL	Water							
Batch R4258599								
WG2894220-24 LCS		**TMRM**						
Calcium (Ca)-Dissolved			103.2		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			96.6		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			99.7		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			97.9		%		80-120	03-OCT-18
Potassium (K)-Dissolved			96.0		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			99.3		%		80-120	03-OCT-18
WG2894220-28 LCS		**TMRM**						
Calcium (Ca)-Dissolved			103.1		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			95.9		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			102.6		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			97.6		%		80-120	03-OCT-18
Potassium (K)-Dissolved			96.8		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			98.8		%		80-120	03-OCT-18
WG2894220-6 LCS		**TMRM**						
Calcium (Ca)-Dissolved			103.6		%		80-120	03-OCT-18
Iron (Fe)-Dissolved			96.7		%		80-120	03-OCT-18
Magnesium (Mg)-Dissolved			100.0		%		80-120	03-OCT-18
Manganese (Mn)-Dissolved			98.0		%		80-120	03-OCT-18
Potassium (K)-Dissolved			97.1		%		80-120	03-OCT-18
Sodium (Na)-Dissolved			98.5		%		80-120	03-OCT-18
WG2894220-1 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-12 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-16 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DIS-ICP-CL	Water							
Batch R4258599								
WG2894220-16 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-19 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-23 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-27 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-5 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-9 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DIS-ICP-CL	Water							
Batch R4258599								
WG2894220-9 MB								
Calcium (Ca)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Iron (Fe)-Dissolved			<0.030		mg/L		0.03	03-OCT-18
Magnesium (Mg)-Dissolved			<0.10		mg/L		0.1	03-OCT-18
Manganese (Mn)-Dissolved			<0.0050		mg/L		0.005	03-OCT-18
Potassium (K)-Dissolved			<0.50		mg/L		0.5	03-OCT-18
Sodium (Na)-Dissolved			<1.0		mg/L		1	03-OCT-18
WG2894220-15 MS		**L2164033-6**						
Calcium (Ca)-Dissolved			100.6		%		70-130	03-OCT-18
Iron (Fe)-Dissolved			95.9		%		70-130	03-OCT-18
Magnesium (Mg)-Dissolved			93.5		%		70-130	03-OCT-18
Potassium (K)-Dissolved			95.4		%		70-130	03-OCT-18
Sodium (Na)-Dissolved			95.8		%		70-130	03-OCT-18
MET-T-CCMS-CL	Water							
Batch R4253268								
WG2891783-2 LCS		**TMRM**						
Aluminum (Al)-Total			104.3		%		80-120	01-OCT-18
Antimony (Sb)-Total			105.8		%		80-120	01-OCT-18
Arsenic (As)-Total			101.2		%		80-120	01-OCT-18
Barium (Ba)-Total			98.1		%		80-120	01-OCT-18
Beryllium (Be)-Total			104.4		%		80-120	01-OCT-18
Bismuth (Bi)-Total			104.9		%		80-120	01-OCT-18
Boron (B)-Total			115.4		%		80-120	01-OCT-18
Cadmium (Cd)-Total			96.1		%		80-120	01-OCT-18
Cesium (Cs)-Total			103.4		%		80-120	01-OCT-18
Chromium (Cr)-Total			104.1		%		80-120	01-OCT-18
Cobalt (Co)-Total			97.7		%		80-120	01-OCT-18
Copper (Cu)-Total			99.6		%		80-120	01-OCT-18
Lead (Pb)-Total			107.3		%		80-120	01-OCT-18
Lithium (Li)-Total			112.6		%		80-120	01-OCT-18
Molybdenum (Mo)-Total			103.2		%		80-120	01-OCT-18
Nickel (Ni)-Total			100.9		%		80-120	01-OCT-18
Phosphorus (P)-Total			117.2		%		70-130	01-OCT-18
Rubidium (Rb)-Total			103.8		%		80-120	01-OCT-18
Selenium (Se)-Total			101.5		%		80-120	01-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch **R4253268**								
WG2891783-2 LCS		**TMRM**						
Silicon (Si)-Total			102.9		%		60-140	01-OCT-18
Silver (Ag)-Total			101.0		%		80-120	01-OCT-18
Strontium (Sr)-Total			103.3		%		80-120	01-OCT-18
Sulfur (S)-Total			112.7		%		80-120	01-OCT-18
Tellurium (Te)-Total			104.6		%		80-120	01-OCT-18
Thallium (Tl)-Total			101.1		%		80-120	01-OCT-18
Thorium (Th)-Total			107.7		%		80-120	01-OCT-18
Tin (Sn)-Total			98.3		%		80-120	01-OCT-18
Titanium (Ti)-Total			103.9		%		80-120	01-OCT-18
Tungsten (W)-Total			105.5		%		80-120	01-OCT-18
Uranium (U)-Total			99.95		%		80-120	01-OCT-18
Vanadium (V)-Total			101.7		%		80-120	01-OCT-18
Zinc (Zn)-Total			97.2		%		80-120	01-OCT-18
Zirconium (Zr)-Total			102.8		%		80-120	01-OCT-18
WG2891783-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	01-OCT-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Boron (B)-Total			<0.010		mg/L		0.01	01-OCT-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	01-OCT-18
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	01-OCT-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	01-OCT-18
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	01-OCT-18
Selenium (Se)-Total			<0.000050		mg/L		0.00005	01-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4253268								
WG2891783-1 MB								
Silicon (Si)-Total			<0.10		mg/L		0.1	01-OCT-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	01-OCT-18
Sulfur (S)-Total			<0.50		mg/L		0.5	01-OCT-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	01-OCT-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Tin (Sn)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	01-OCT-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	01-OCT-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	01-OCT-18
Batch R4256952								
WG2891783-5 LCS		**TMRM**						
Aluminum (Al)-Total			107.5		%		80-120	01-OCT-18
Antimony (Sb)-Total			112.5		%		80-120	01-OCT-18
Arsenic (As)-Total			100.9		%		80-120	01-OCT-18
Barium (Ba)-Total			107.4		%		80-120	01-OCT-18
Beryllium (Be)-Total			98.3		%		80-120	01-OCT-18
Bismuth (Bi)-Total			101.2		%		80-120	01-OCT-18
Boron (B)-Total			84.3		%		80-120	01-OCT-18
Cadmium (Cd)-Total			102.2		%		80-120	01-OCT-18
Cesium (Cs)-Total			108.6		%		80-120	01-OCT-18
Chromium (Cr)-Total			109.3		%		80-120	01-OCT-18
Cobalt (Co)-Total			108.6		%		80-120	01-OCT-18
Copper (Cu)-Total			104.4		%		80-120	01-OCT-18
Lead (Pb)-Total			104.7		%		80-120	01-OCT-18
Lithium (Li)-Total			104.0		%		80-120	01-OCT-18
Molybdenum (Mo)-Total			110.8		%		80-120	01-OCT-18
Nickel (Ni)-Total			106.3		%		80-120	01-OCT-18
Phosphorus (P)-Total			107.4		%		70-130	01-OCT-18
Rubidium (Rb)-Total			102.8		%		80-120	01-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch **R4256952**								
WG2891783-5 LCS		**TMRM**						
Selenium (Se)-Total			100.2		%		80-120	01-OCT-18
Silicon (Si)-Total			107.6		%		60-140	01-OCT-18
Silver (Ag)-Total			105.6		%		80-120	01-OCT-18
Strontium (Sr)-Total			110.6		%		80-120	01-OCT-18
Sulfur (S)-Total			97.9		%		80-120	01-OCT-18
Tellurium (Te)-Total			95.8		%		80-120	01-OCT-18
Thallium (Tl)-Total			102.4		%		80-120	01-OCT-18
Thorium (Th)-Total			103.7		%		80-120	01-OCT-18
Tin (Sn)-Total			107.7		%		80-120	01-OCT-18
Titanium (Ti)-Total			100.5		%		80-120	01-OCT-18
Tungsten (W)-Total			105.0		%		80-120	01-OCT-18
Uranium (U)-Total			106.1		%		80-120	01-OCT-18
Vanadium (V)-Total			107.3		%		80-120	01-OCT-18
Zinc (Zn)-Total			105.8		%		80-120	01-OCT-18
Zirconium (Zr)-Total			108.9		%		80-120	01-OCT-18
WG2891783-4 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	01-OCT-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Boron (B)-Total			<0.010		mg/L		0.01	01-OCT-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	01-OCT-18
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	01-OCT-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	01-OCT-18
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	01-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4256952								
WG2891783-4 MB								
Selenium (Se)-Total			<0.000050		mg/L		0.00005	01-OCT-18
Silicon (Si)-Total			<0.10		mg/L		0.1	01-OCT-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	01-OCT-18
Sulfur (S)-Total			<0.50		mg/L		0.5	01-OCT-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	01-OCT-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Tin (Sn)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	01-OCT-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	01-OCT-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	01-OCT-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	01-OCT-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	01-OCT-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	01-OCT-18
Batch R4258478								
WG2891783-6 DUP		**L2164033-1**						
Aluminum (Al)-Total		0.0155	0.0160		mg/L	3.0	20	02-OCT-18
Antimony (Sb)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Arsenic (As)-Total		0.00035	0.00034		mg/L	2.5	20	02-OCT-18
Barium (Ba)-Total		0.0413	0.0414		mg/L	0.2	20	02-OCT-18
Beryllium (Be)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Bismuth (Bi)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Boron (B)-Total		0.075	0.076		mg/L	1.4	20	02-OCT-18
Cadmium (Cd)-Total		<0.0000050	<0.0000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Cesium (Cs)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Chromium (Cr)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Cobalt (Co)-Total		0.00016	0.00017		mg/L	1.9	20	02-OCT-18
Copper (Cu)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	02-OCT-18
Lead (Pb)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	02-OCT-18
Lithium (Li)-Total		0.0101	0.0102		mg/L	0.8	20	02-OCT-18
Molybdenum (Mo)-Total		0.000360	0.000376		mg/L	4.2	20	02-OCT-18
Nickel (Ni)-Total		0.00098	0.00102		mg/L	3.5	20	02-OCT-18
Phosphorus (P)-Total		<0.050	<0.050	RPD-NA	mg/L	N/A	20	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4258478								
WG2891783-6 DUP		**L2164033-1**						
Rubidium (Rb)-Total		0.00151	0.00144		mg/L	4.7	20	02-OCT-18
Selenium (Se)-Total		0.000060	0.000057		mg/L	6.3	20	02-OCT-18
Silicon (Si)-Total		3.62	3.68		mg/L	1.6	20	02-OCT-18
Silver (Ag)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Strontium (Sr)-Total		0.129	0.131		mg/L	1.3	20	02-OCT-18
Sulfur (S)-Total		7.23	7.35		mg/L	1.6	20	02-OCT-18
Tellurium (Te)-Total		<0.00020	<0.00020	RPD-NA	mg/L	N/A	20	02-OCT-18
Thallium (Tl)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	02-OCT-18
Thorium (Th)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Tin (Sn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Titanium (Ti)-Total		<0.00030	<0.00030	RPD-NA	mg/L	N/A	20	02-OCT-18
Tungsten (W)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	02-OCT-18
Uranium (U)-Total		0.000234	0.000229		mg/L	2.1	20	02-OCT-18
Vanadium (V)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	02-OCT-18
Zinc (Zn)-Total		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	02-OCT-18
Zirconium (Zr)-Total		0.000210	0.000198		mg/L	5.8	20	02-OCT-18
WG2891783-8 LCS		**TMRM**						
Aluminum (Al)-Total			106.0		%		80-120	02-OCT-18
Antimony (Sb)-Total			108.8		%		80-120	02-OCT-18
Arsenic (As)-Total			100.5		%		80-120	02-OCT-18
Barium (Ba)-Total			106.8		%		80-120	02-OCT-18
Beryllium (Be)-Total			96.7		%		80-120	02-OCT-18
Bismuth (Bi)-Total			99.4		%		80-120	02-OCT-18
Boron (B)-Total			98.9		%		80-120	02-OCT-18
Cadmium (Cd)-Total			99.6		%		80-120	02-OCT-18
Cesium (Cs)-Total			102.4		%		80-120	02-OCT-18
Chromium (Cr)-Total			105.9		%		80-120	02-OCT-18
Cobalt (Co)-Total			105.4		%		80-120	02-OCT-18
Copper (Cu)-Total			101.8		%		80-120	02-OCT-18
Lead (Pb)-Total			103.0		%		80-120	02-OCT-18
Lithium (Li)-Total			101.3		%		80-120	02-OCT-18
Molybdenum (Mo)-Total			107.0		%		80-120	02-OCT-18
Nickel (Ni)-Total			102.7		%		80-120	02-OCT-18
Phosphorus (P)-Total			108.1		%		70-130	02-OCT-18

ALS Environmental

Quality Control Report

Workorder: L2164033 Report Date: 11-DEC-18

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4258478								
WG2891783-8 LCS		**TMRM**						
Rubidium (Rb)-Total			101.5		%		80-120	02-OCT-18
Selenium (Se)-Total			94.6		%		80-120	02-OCT-18
Silicon (Si)-Total			105.1		%		60-140	02-OCT-18
Silver (Ag)-Total			103.0		%		80-120	02-OCT-18
Strontium (Sr)-Total			109.0		%		80-120	02-OCT-18
Sulfur (S)-Total			98.8		%		80-120	02-OCT-18
Tellurium (Te)-Total			93.9		%		80-120	02-OCT-18
Thallium (Tl)-Total			99.5		%		80-120	02-OCT-18
Thorium (Th)-Total			100.2		%		80-120	02-OCT-18
Tin (Sn)-Total			103.5		%		80-120	02-OCT-18
Titanium (Ti)-Total			99.2		%		80-120	02-OCT-18
Tungsten (W)-Total			104.3		%		80-120	02-OCT-18
Uranium (U)-Total			103.8		%		80-120	02-OCT-18
Vanadium (V)-Total			106.1		%		80-120	02-OCT-18
Zinc (Zn)-Total			99.1		%		80-120	02-OCT-18
Zirconium (Zr)-Total			106.8		%		80-120	02-OCT-18
WG2891783-7 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	02-OCT-18
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Arsenic (As)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Barium (Ba)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Beryllium (Be)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	02-OCT-18
Boron (B)-Total			<0.010		mg/L		0.01	02-OCT-18
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	02-OCT-18
Cesium (Cs)-Total			<0.000010		mg/L		0.00001	02-OCT-18
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Copper (Cu)-Total			<0.00050		mg/L		0.0005	02-OCT-18
Lead (Pb)-Total			<0.000050		mg/L		0.00005	02-OCT-18
Lithium (Li)-Total			<0.0010		mg/L		0.001	02-OCT-18
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	02-OCT-18
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	02-OCT-18
Phosphorus (P)-Total			<0.050		mg/L		0.05	02-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-CL	Water							
Batch R4258478								
WG2891783-7 MB								
Rubidium (Rb)-Total			<0.00020		mg/L		0.0002	02-OCT-18
Selenium (Se)-Total			<0.000050		mg/L		0.00005	02-OCT-18
Silicon (Si)-Total			<0.10		mg/L		0.1	02-OCT-18
Silver (Ag)-Total			<0.000010		mg/L		0.00001	02-OCT-18
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	02-OCT-18
Sulfur (S)-Total			<0.50		mg/L		0.5	02-OCT-18
Tellurium (Te)-Total			<0.00020		mg/L		0.0002	02-OCT-18
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	02-OCT-18
Thorium (Th)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Tin (Sn)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	02-OCT-18
Tungsten (W)-Total			<0.00010		mg/L		0.0001	02-OCT-18
Uranium (U)-Total			<0.000010		mg/L		0.00001	02-OCT-18
Vanadium (V)-Total			<0.00050		mg/L		0.0005	02-OCT-18
Zinc (Zn)-Total			<0.0030		mg/L		0.003	02-OCT-18
Zirconium (Zr)-Total			<0.000060		mg/L		0.00006	02-OCT-18
MET-TOT-ICP-CL	Water							
Batch R4254374								
WG2891783-2 LCS		**TMRM**						
Calcium (Ca)-Total			97.4		%		80-120	01-OCT-18
Iron (Fe)-Total			102.9		%		80-120	01-OCT-18
Magnesium (Mg)-Total			103.6		%		80-120	01-OCT-18
Manganese (Mn)-Total			95.6		%		80-120	01-OCT-18
Potassium (K)-Total			101.8		%		80-120	01-OCT-18
Sodium (Na)-Total			102.8		%		80-120	01-OCT-18
WG2891783-1 MB								
Calcium (Ca)-Total			<0.10		mg/L		0.1	01-OCT-18
Iron (Fe)-Total			<0.030		mg/L		0.03	01-OCT-18
Magnesium (Mg)-Total			<0.10		mg/L		0.1	01-OCT-18
Manganese (Mn)-Total			<0.0050		mg/L		0.005	01-OCT-18
Potassium (K)-Total			<0.50		mg/L		0.5	01-OCT-18
Sodium (Na)-Total			<1.0		mg/L		1	01-OCT-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-TOT-ICP-CL	Water							
Batch R4257716								
WG2891783-5 LCS		**TMRM**						
Calcium (Ca)-Total			101.0		%		80-120	02-OCT-18
Iron (Fe)-Total			95.2		%		80-120	02-OCT-18
Magnesium (Mg)-Total			100.1		%		80-120	02-OCT-18
Manganese (Mn)-Total			97.2		%		80-120	02-OCT-18
Potassium (K)-Total			96.2		%		80-120	02-OCT-18
Sodium (Na)-Total			102.5		%		80-120	02-OCT-18
WG2891783-4 MB								
Calcium (Ca)-Total			<0.10		mg/L		0.1	02-OCT-18
Iron (Fe)-Total			<0.030		mg/L		0.03	02-OCT-18
Magnesium (Mg)-Total			<0.10		mg/L		0.1	02-OCT-18
Manganese (Mn)-Total			<0.0050		mg/L		0.005	02-OCT-18
Potassium (K)-Total			<0.50		mg/L		0.5	02-OCT-18
Sodium (Na)-Total			<1.0		mg/L		1	02-OCT-18
NAPHTHENIC ACID-L-FM	Water							
Batch R4223648								
WG2878323-4 DUP		**L2164033-6**						
Naphthenic Acids		<0.10	<0.10	RPD-NA	mg/L	N/A	30	19-SEP-18
WG2878323-2 LCS								
Naphthenic Acids			91.0		%		70-130	19-SEP-18
WG2878323-1 MB								
Naphthenic Acids			<0.10		mg/L		0.1	19-SEP-18
WG2878323-3 MS		**L2164033-5**						
Naphthenic Acids			101.5		%		50-150	19-SEP-18
NH3-COL-ED	Water							
Batch R4216414								
WG2876845-7 DUP		**L2164033-6**						
Ammonia, Total (as N)		<0.050	<0.050	RPD-NA	mg/L	N/A	20	14-SEP-18
WG2876845-10 LCS								
Ammonia, Total (as N)			110.7		%		85-115	14-SEP-18
WG2876845-12 LCS								
Ammonia, Total (as N)			107.5		%		85-115	14-SEP-18
WG2876845-2 LCS								
Ammonia, Total (as N)			102.9		%		85-115	14-SEP-18
WG2876845-1 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	14-SEP-18
WG2876845-11 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NH3-COL-ED	Water							
Batch R4216414								
WG2876845-11 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	14-SEP-18
WG2876845-9 MB								
Ammonia, Total (as N)			<0.050		mg/L		0.05	14-SEP-18
WG2876845-8 MS		**L2164033-6**						
Ammonia, Total (as N)			115.0		%		75-125	14-SEP-18
NO2-IC-N-ED	Water							
Batch R4216859								
WG2875838-11 LCS								
Nitrite (as N)			95.3		%		90-110	13-SEP-18
WG2875838-13 LCS								
Nitrite (as N)			95.5		%		90-110	14-SEP-18
WG2875838-15 LCS								
Nitrite (as N)			93.7		%		90-110	14-SEP-18
WG2875838-2 LCS								
Nitrite (as N)			96.1		%		90-110	13-SEP-18
WG2875838-1 MB								
Nitrite (as N)			<0.010		mg/L		0.01	13-SEP-18
WG2875838-12 MB								
Nitrite (as N)			<0.010		mg/L		0.01	13-SEP-18
WG2875838-14 MB								
Nitrite (as N)			<0.010		mg/L		0.01	14-SEP-18
WG2875838-16 MB								
Nitrite (as N)			<0.010		mg/L		0.01	14-SEP-18
NO3-IC-N-ED	Water							
Batch R4216859								
WG2875838-11 LCS								
Nitrate (as N)			98.9		%		90-110	13-SEP-18
WG2875838-13 LCS								
Nitrate (as N)			99.0		%		90-110	14-SEP-18
WG2875838-15 LCS								
Nitrate (as N)			98.0		%		90-110	14-SEP-18
WG2875838-2 LCS								
Nitrate (as N)			98.6		%		90-110	13-SEP-18
WG2875838-1 MB								
Nitrate (as N)			<0.020		mg/L		0.02	13-SEP-18
WG2875838-12 MB								
Nitrate (as N)			<0.020		mg/L		0.02	13-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-IC-N-ED	Water							
Batch R4216859								
WG2875838-14 MB								
Nitrate (as N)			<0.020		mg/L		0.02	14-SEP-18
WG2875838-16 MB								
Nitrate (as N)			<0.020		mg/L		0.02	14-SEP-18
P-T-L-COL-ED	Water							
Batch R4217003								
WG2877251-2 LCS								
Phosphorus (P)-Total			96.0		%		80-120	15-SEP-18
WG2877251-1 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	15-SEP-18
Batch R4220108								
WG2878635-6 LCS								
Phosphorus (P)-Total			91.2		%		80-120	18-SEP-18
WG2878635-5 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	18-SEP-18
P-TD-L-COL-ED	Water							
Batch R4217003								
WG2877251-2 LCS								
Phosphorus (P)-Total Dissolved			96.0		%		80-120	15-SEP-18
WG2877251-1 MB								
Phosphorus (P)-Total Dissolved			<0.0010		mg/L		0.001	15-SEP-18
Batch R4220108								
WG2878635-6 LCS								
Phosphorus (P)-Total Dissolved			92.0		%		80-120	18-SEP-18
WG2878635-5 MB								
Phosphorus (P)-Total Dissolved			<0.0010		mg/L		0.001	18-SEP-18
PH/EC/ALKS-ED	Water							
Batch R4216885								
WG2877626-13 LCS		**MID_1412**						
Conductivity (EC)			98.5		%		90-110	15-SEP-18
WG2877626-14 LCS		**ED-PH6**						
pH			6.00		pH		5.8-6.2	15-SEP-18
WG2877626-15 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			111.5		%		85-115	15-SEP-18
WG2877626-16 LCS		**HI_12890**						
Conductivity (EC)			90.8		%		90-110	15-SEP-18
WG2877626-18 LCS		**MID_1412**						
Conductivity (EC)			99.8		%		90-110	15-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH/EC/ALKS-ED	Water							
Batch R4216885								
WG2877626-19 LCS		**ED-PH6**						
pH			5.99		pH		5.8-6.2	15-SEP-18
WG2877626-2 LCS		**MID_1412**						
Conductivity (EC)			97.5		%		90-110	15-SEP-18
WG2877626-20 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			113.1		%		85-115	15-SEP-18
WG2877626-21 LCS		**HI_12890**						
Conductivity (EC)			94.3		%		90-110	15-SEP-18
WG2877626-23 LCS		**MID_1412**						
Conductivity (EC)			103.1		%		90-110	15-SEP-18
WG2877626-24 LCS		**ED-PH6**						
pH			5.98		pH		5.8-6.2	15-SEP-18
WG2877626-25 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			113.7		%		85-115	15-SEP-18
WG2877626-26 LCS		**HI_12890**						
Conductivity (EC)			95.1		%		90-110	15-SEP-18
WG2877626-28 LCS		**MID_1412**						
Conductivity (EC)			96.7		%		90-110	15-SEP-18
WG2877626-29 LCS		**ED-PH6**						
pH			5.99		pH		5.8-6.2	15-SEP-18
WG2877626-3 LCS		**ED-PH6**						
pH			6.01		pH		5.8-6.2	15-SEP-18
WG2877626-30 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			113.2		%		85-115	15-SEP-18
WG2877626-31 LCS		**HI_12890**						
Conductivity (EC)			96.2		%		90-110	15-SEP-18
WG2877626-33 LCS		**MID_1412**						
Conductivity (EC)			95.2		%		90-110	15-SEP-18
WG2877626-34 LCS		**ED-PH6**						
pH			5.99		pH		5.8-6.2	15-SEP-18
WG2877626-35 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			112.3		%		85-115	15-SEP-18
WG2877626-36 LCS		**HI_12890**						
Conductivity (EC)			91.5		%		90-110	15-SEP-18
WG2877626-38 LCS		**MID_1412**						
Conductivity (EC)			96.1		%		90-110	15-SEP-18
WG2877626-39 LCS		**ED-PH6**						
pH			5.99		pH		5.8-6.2	15-SEP-18
WG2877626-4 LCS		**PCTITRATE_LCS**						

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH/EC/ALKS-ED	Water							
Batch R4216885								
WG2877626-4 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			112.3		%		85-115	15-SEP-18
WG2877626-40 LCS		**PCTITRATE_LCS**						
Alkalinity, Total (as CaCO3)			111.1		%		85-115	15-SEP-18
WG2877626-41 LCS		**HI_12890**						
Conductivity (EC)			94.1		%		90-110	15-SEP-18
WG2877626-5 LCS		**HI_12890**						
Conductivity (EC)			93.3		%		90-110	15-SEP-18
WG2877626-1 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-12 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-17 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-22 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-27 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PH/EC/ALKS-ED	Water							
Batch R4216885								
WG2877626-27 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-32 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
WG2877626-37 MB								
Conductivity (EC)			<2.0		uS/cm		2	15-SEP-18
Bicarbonate Alkalinity (as HCO3)			<5.0		mg/L		5	15-SEP-18
Carbonate Alkalinity (as CO3)			<5.0		mg/L		5	15-SEP-18
Hydroxide Alkalinity (as OH)			<5.0		mg/L		5	15-SEP-18
Alkalinity, Phenolphthalein (as CaCO3)			<2.0		mg/L		2	15-SEP-18
Alkalinity, Total (as CaCO3)			<2.0		mg/L		2	15-SEP-18
PHENOLS-4AAP-WT	Water							
Batch R4231049								
WG2882956-2 LCS								
Phenols (4AAP)			98.7		%		85-115	21-SEP-18
WG2882956-1 MB								
Phenols (4AAP)			<0.0010		mg/L		0.001	21-SEP-18
Batch R4256907								
WG2892003-3 DUP		**L2164033-5**						
Phenols (4AAP)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	01-OCT-18
WG2892003-2 LCS								
Phenols (4AAP)			95.1		%		85-115	01-OCT-18
WG2892003-1 MB								
Phenols (4AAP)			<0.0010		mg/L		0.001	01-OCT-18
WG2892003-4 MS		**L2164033-5**						
Phenols (4AAP)			99.2		%		75-125	01-OCT-18
PO4-DO-COL-ED	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-ED	Water							
Batch R4216405								
WG2876821-5 DUP		**L2164033-5**						
Orthophosphate-Dissolved (as P)		<0.010	<0.010	RPD-NA	mg/L	N/A	20	14-SEP-18
WG2876821-2 LCS								
Orthophosphate-Dissolved (as P)			117.4		%		80-120	14-SEP-18
WG2876821-1 MB								
Orthophosphate-Dissolved (as P)			<0.010		mg/L		0.01	14-SEP-18
WG2876821-6 MS		**L2164033-5**						
Orthophosphate-Dissolved (as P)			91.1		%		70-130	14-SEP-18
SO4-IC-N-ED	Water							
Batch R4216859								
WG2875838-11 LCS								
Sulfate (SO4)			98.6		%		90-110	13-SEP-18
WG2875838-13 LCS								
Sulfate (SO4)			99.5		%		90-110	14-SEP-18
WG2875838-15 LCS								
Sulfate (SO4)			98.4		%		90-110	14-SEP-18
WG2875838-2 LCS								
Sulfate (SO4)			98.8		%		90-110	13-SEP-18
WG2875838-1 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	13-SEP-18
WG2875838-12 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	13-SEP-18
WG2875838-14 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	14-SEP-18
WG2875838-16 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	14-SEP-18
SOLIDS-TDS-FM	Water							
Batch R4227997								
WG2880643-3 DUP		**L2164033-1**						
Total Dissolved Solids		216	212		mg/L	1.6	20	19-SEP-18
WG2880643-2 LCS								
Total Dissolved Solids			89.5		%		85-115	19-SEP-18
WG2880643-1 MB								
Total Dissolved Solids			<12		mg/L		12	19-SEP-18
SOLIDS-TOTSUS-FM	Water							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SOLIDS-TOTSUS-FM	Water							
Batch R4228387								
WG2876665-2 LCS								
Total Suspended Solids			98.6		%		85-115	20-SEP-18
WG2876665-1 MB								
Total Suspended Solids			<3.0		mg/L		3	20-SEP-18
SULPHIDE-CFA-ED	Water							
Batch R4228788								
WG2881863-17 DUP		**L2164033-6**						
Sulphide (as S)		<0.0015	<0.0015	RPD-NA	mg/L	N/A	20	19-SEP-18
WG2881863-10 LCS								
Sulphide (as S)			105.7		%		75-125	19-SEP-18
WG2881863-7 LCS								
Sulphide (as S)			117.5		%		75-125	19-SEP-18
WG2881863-8 LCS								
Sulphide (as S)			91.3		%		75-125	19-SEP-18
WG2881863-9 LCS								
Sulphide (as S)			91.9		%		75-125	19-SEP-18
WG2881863-1 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-2 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-3 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-4 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-5 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-6 MB								
Sulphide (as S)			<0.0015		mg/L		0.0015	19-SEP-18
WG2881863-20 MS		**L2164033-6**						
Sulphide (as S)			91.4		%		65-135	19-SEP-18
TKN-CFA-ED	Water							
Batch R4259914								
WG2894559-6 LCS								
Total Kjeldahl Nitrogen			101		%		75-125	04-OCT-18
WG2894559-5 MB								
Total Kjeldahl Nitrogen			<0.20		mg/L		0.2	04-OCT-18

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Inorganic Parameters							
Chlorine, Total							
	1	13-SEP-18 10:00	14-SEP-18 12:00	0.25	26	hours	EHTR-FM
	2	13-SEP-18 11:00	14-SEP-18 12:00	0.25	25	hours	EHTR-FM
	3	13-SEP-18 11:45	14-SEP-18 12:00	0.25	24	hours	EHTR-FM
	4	13-SEP-18 13:00	14-SEP-18 12:00	0.25	23	hours	EHTR-FM
	5	13-SEP-18 12:00	14-SEP-18 12:00	0.25	24	hours	EHTR-FM
	6	13-SEP-18	14-SEP-18 12:00	0.25	24	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L2164033 were received on 13-SEP-18 16:56.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

s.19(1)

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L2164033-COFC

COC Number: 17 - 658112

Page 1 of 1

Report To	Contact and company name below will appear on the final report
Company:	Hatfield Consultants
Contact:	Chris Sneade or Andrew O'Gorman
Phone:	604-338-2474 or 780-743-4290
	Company address below will appear on the final report
Street:	Suite A, 300 Mackenzie Blvd.
City/Province:	Fort McMurray, AB
Postal Code:	T9H 4C4

Report Format / Distribution

Select Report Format: ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL)
Quality Control (QC) Report with Report ☑ YES ☐ NO
☐ Compare Results to Criteria on Report - provide details below if box checked
Select Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax:
Email 2:
Email 3:

Select Service Level Below - Contact your AM to confirm all E&P TATs (surcharges may apply)

Regular [R] ☑ Standard TAT if received by 3 pm - business days - no surcharges apply
PRIORITY (Business Days): 4 day [P4-20%] ☐ 3 day [P3-25%] ☐ 2 day [P2-50%] ☐
EMERGENCY: 1 Business day [E-100%] ☐ Same Day, Weekend or Statutory holiday [E2-200% (Laboratory opening fees may apply)] ☐
Date and Time Required for all E&P TATs:
For tests that can not be performed according to the service level selected, you will be contacted.

Invoice To	
Same as Report To	☑ YES ☐ NO
Copy of Invoice with Report	☐ YES ☐ NO
Company:	
Contact:	

Invoice Distribution

Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax: Same as report
Email 2:

Project Information

ALS Account # / Quote #:	Q69154
Job #:	
PO / AFE:	CNUL9184
LSD:	

Oil and Gas Required Fields (client use)

AFE/Cost Center:		PO#	
Major/Minor Code:		Routing Code:	
Requisitioner:			
Location:			

ALS Lab Work Order # (lab use only):

ALS Contact: | Sampler:

Analysis Request — Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Q69154	Samples on Hold	Sample is hazardous (please provide further details)	Number of Containers
	Buoy Top	13-09-18	10:00	SW	✓			13
	Buoy Bottom	13-09-18	11:00	SW	✓			13
	Outlet	13-09-18	11:45	SW	✓			13
	Duplicate	13-09-18	13:00	SW	✓			13
	TB (trip blank)	13-09-18	—	SW	✓			11

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System? ☐ YES ☐ NO
Are samples for human consumption/ use? ☐ YES ☐ NO

Special Instructions / Specify Criteria to add on report by clicking on the drop-down list below (electronic COC only)

All dissolved parameters are not field filtered and not preserved in all bottle sets

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐
Ice Packs ☐ Ice Cubes ☐ Custody seal intact Yes ☐ No ☐
Cooling Initiated ☐
INITIAL COOLER TEMPERATURES °C: 5.0°C
FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date: Sept 13/18	Time: 16:04	Received by:	Date: [illegible]	Time: 4:05	Received by	Date	Time

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY YELLOW - CLIENT COPY

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

JULY 2017 FRONT

Appendix A4

Sediment Quality Data

Maxxam
A Bureau Veritas Group Company

maxxam.ca

MAXXAM ANALYTICS
4606 Canada Way
Burnaby, BC V5G 1K5

Office 604 734 7276
Toll Free 800 665 8566
Fax 604 731 2386

FRESHWATER SEDIMENT TOXICITY TESTING USING *CHIRONOMUS DILUTUS* AND *HYALELLA AZTECA*

Prepared for:
Hatfield Consultants
Suite A, 300 MacKenzie Blvd
Fort McMurray, AB
Canada, T9H 4C4

Prepared by:
Ecotoxicology Group
Maxxam Analytics
Maxxam Job #: B872132
October 2018

EXECUTIVE SUMMARY

Three freshwater sediment samples were collected on August 23, 2018 for testing. The samples arrived at Maxxam Analytics Fort McMurray location, in good condition, on August 24, 2018.

The following freshwater sediment toxicity tests were conducted on the samples; a 10 day survival and growth test with the freshwater midge, *Chironomus dilutus,* and a 14 day survival and growth test with the freshwater amphipod, *Hyalella azteca*.

Both the *Chironomus* test and the *Hyalella* test were initiated within their respective hold times with the *Hyalella* test ending on September 27, 2018 and the *Chironomus* test ending on October 5, 2018. All sample results were statistically assessed against a negative control for both tests.

Details regarding the test results, methods, test conditions, organism acclimation, and quality control measures are summarised within the report. All tabulated data, raw data, and associated supporting documents are located within the report appendices.

Each test was considered valid as survival and growth in the negative control(s) met the validity criteria outlined in the associated reference methods.

TABLE OF CONTENTS

LIST OF TABLES

SECTION

1 SEDIMENT DESCRIPTION

1.1 Sample Information

Three freshwater sediment samples were collected on August 23, 2018 for testing. The samples arrived at Maxxam Analytics Fort McMurray location, in good condition, on August 24, 2018.

All tests were initiated within their respective hold times. Sample information, including sample descriptions, porewater ammonia analyses, and water quality data are located in Appendix A. Upon opening the sample containers, a description of each sample was recorded ("Sediment Sample Descriptions" in Appendix A).

Prior to testing, each field replicate was homogenized, using a stainless steel spoon. Any headspace in the sample container was purged with nitrogen gas prior to re-sealing it in order to prevent oxidation of the sediment during storage. When not in use, the sediments were stored in the dark at 4 ± 2°C.

1.2 Negative Control Sediment

The control sediment (negative control) for the toxicity tests was collected from Yaquina Bay, Newport, Oregon, by staff of Northwestern Aquatic Sciences. This beach sand has been used as a negative control in previous studies within our laboratory, and has been found to be non-toxic to a variety of organisms. It was wet sieved through 500 µm stainless steel mesh and thoroughly washed with the appropriate control water before use in the tests.

Table 1-1 Physiochemical Characterisation of Yaquina Bay Beach Sand

Total Organic Carbon (mg/kg)	Moisture Content (%)	Sand (%)	Silt (%)	Clay (%)
<500	16	98	2.4	<2.0

1.3 Porewater Characterization

On Day -1 of *Chironomus* testing, a seventh replicate of each sample was prepared, filled with reconstituted control water and aerated overnight, along with the test vessels. The following morning, the overlying water in the seventh replicate of each sample was decanted and aliquots of the sediment were distributed into 500 mL polycarbonate bottles. Nitrogen gas was placed over the sediments prior to centrifuging for 20 minutes at ~5,000 rpm. The resulting porewater was carefully decanted and analysed for ammonia, pH, and temperature.

Analysis of ammonia in porewater was performed at the Maxxam Environmental Inorganic Water Laboratory. The total ammonia concentrations as N (mg/L) in the samples, was measured under basic conditions using the Berthelot reaction in the presence of EDTA. A sample was treated sequentially until a blue indophenol complex formed, which could then be measured photometrically at 660 nm.

Results of the ammonia, temperature, and pH in porewater analyses for each of the test samples are available in Appendix A.

SECTION

2 10 DAY *CHIRONOMUS DILUTUS* SURVIVAL AND GROWTH TEST

2.1 Test Methods

The survival and growth of *Chironomus dilutus* larvae, when exposed to whole sediment samples for 10 days, was assessed according to the Maxxam Standard Operating Procedure: *Chironomus dilutus* 10-Day Survival and Growth Test (BBY2SOP-00010), which is based on the Environment Canada Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*) (EPS 1/RM/32).

One day prior to test initiation, the field replicates were individually homogenized, and a 100 mL aliquot was distributed into a 375 mL labelled test vessel. Reconstituted moderately hard water was then slowly added to the vessel by pouring a stream of water onto a Plexiglas baffle to minimize disturbing the sediment layer. The test vessels were then randomized on the bench top, and airlines and lids were fitted to each test vessel.

A composite sample was produced by combining equal portions of each field replicate. Then, 100 mL of the composite sample was distributed into the sixth and seventh replicate test vessels for water quality and porewater measurements.

The following day, aliquots of overlying water were removed from the test vessels for initial overlying water chemistry. The sixth replicate test vessel was used for water quality measurements for the duration of the test and the seventh replicate was decanted and centrifuged to extract porewater for ammonia, temperature, and pH measurements (see Section 1.3). To initiate the test, ten larval chironomids were randomly selected from their holding containers and directly seeded into the test vessels.

During the test, daily observations and aeration checks were performed. Temperature and dissolved oxygen measurements were taken three times per week in the test vessels designated for water quality measurements. Test vessels were also fed 3.75 mL Tetramin™ flakes, prepared as a 4 g dry solids/L slurry, on the days water quality measurements were taken.

At test termination, the contents of each test vessel were sieved through a 500 µm sieve in order to retrieve the live larval midges. The number of larvae found was recorded along with any other observations made. The organisms were then placed into pre-weighed aluminum weigh boats that were subsequently placed into a ~60°C drying oven for >24 hours. Missing chironomids were presumed to have died and decomposed during the test. Any larval midges that had reached the pupal or adult stage of development were excluded from the dry weight analysis, if applicable.

2.2 Organism Information

2.2.1 Organism Acclimation and Holding Information

One batch of laboratory-reared *Chironomus dilutus* larvae was received from Aquatic Biosystems on September 25, 2018. The midge larvae were shipped in 1L plastic containers filled with unbleached paper towels and overlying moderately hard water. Prior to shipping, the headspace in each container was filled with oxygen gas of a sufficient concentration to maintain adequate saturation levels in the shipping water. They were shipped directly for overnight delivery to Maxxam and arrived without incident.

Upon arrival at Maxxam, the water quality of the shipping water was measured and compared to the test conditions. Gentle aeration was supplied to each shipping container. Any moribund or deceased larvae were removed and recorded on the acclimation sheet, if applicable (Appendix B).

The chironomid larvae were not fed during the holding period as they were used the same day. Historically at Maxxam, it has been determined that little to no acclimation is required as long as the shipping, testing, and supplier laboratory conditions are similar.

2.2.2 Organism Health

The mortality rate during shipping did not exceed 10% overall. Bench sheets with the receiving water quality and observations of the number dead or inactive larvae are available in Appendix B.

2.2.3 Organism Age

At test initiation, 20 representative larvae were euthanized and their head capsule widths were measured to the nearest 0.01 mm, using an inverted microscope outfitted with an ocular micrometer. The average head capsule width of the organism batch was determined to within the 0.33 – 0.45 mm range, which indicated they were the recommended age (see Table 2-1).

2.3 Test Conditions

See Table 2-1 for a detailed list of the test conditions. All bench sheets used to record raw data are available in Appendix B.

Table 2-1 Test Conditions for the 10-day *Chironomus dilutus* Test

Parameter	Conditions and Methods
Test Type and Duration	10 Day, Static (non-renewal)
Temperature	Average daily temperature 23 ± 1 °C; instantaneous temperature 23 ± 3 °C.
Photoperiod and Light Intensity	16 hours light: 8 hours dark. Wide spectrum cool white fluorescent lights used to provide 622 - 741 lux.
Aeration	< 100 bubbles/ minute. Clean oil-free air supplied to each test vessel via micro-bore plastic tubing.
Test Chamber	375 mL glass jars with plastic lids containing small opening for airline tubing.
Sediment Volume	100 mL of each homogenized field replicate (3-4 cm depth).
Porewater Water Quality	Temperature, pH, and ammonia.
Overlying Water Source and Volume	175 mL (~5-6 cm depth); Reconstituted Moderately Hard Water; warmed to 23 ± 1°C and aerated >24 hours before use.
Overlying Water Quality	Temperature, pH, dissolved oxygen, conductance, hardness, alkalinity, and ammonia measurements on Day 0 and Day 10 of the test. Temperature and dissolved oxygen were also measured three times weekly during the test.
Replicates	5 replicates per sample, plus 2 additional replicates for water quality measurements and porewater analyses.
Control Sediment (Negative Control)	Yaquina Bay Sand, rinsed with control water and sieved through a 500 µm stainless steel mesh.
Reference Sediment	None
Feeding	3.75 mL Tetramin™ flakes as slurry (4g dry solids/L) per vessel, three times weekly.
Organisms/ replicate	10
Organism Source	Aquatic Biosystems, Fort Collins, Colorado.
Mortality during acclimation	0.0%
Mean Head capsule width and organism age	0.34 ± 0.05 mm; 3rd instar larval midges
Endpoints	Mean Survival and Growth
Test Validity Criteria	≥70% mean survival in the negative controls. >0.6 mg mean dry weight in the negative controls.
Statistical Software	CETIS™ version 1.9.2.4. Tidepool Scientific Software (Copyright 2009-2016).

2.4 Quality Assurance/Quality Control

2.4.1 Reference Toxicant Results

A 96 hour reference toxicant test, or positive control test, was conducted alongside the sediment test. The water-only test, using copper sulphate ($CuSO_4$), was initiated to aid in the assessment of organism sensitivity and the precision of the results. The resulting LC50 was then compared in a control chart against the results of previous tests. Table 2-2 summarises the result of the reference toxicant test.

The calculated LC50 for the reference toxicant test was within two standard deviations (95%) range of the historic mean LC50. This supports the assumption that the sensitivity of the organism batch was comparable to batches previously test in this laboratory.

A reference toxicant test is only one of the tools used to assess the health of an organism. Natural variability accounts for the spread in reference toxicant LC50s. The method used in preparing the control charts was based on from "Ecotoxicology Control Charting" (COR2WI-00002).

Table 2-2 Reference Toxicant Test Result for *Chironomus dilutus*

Organism Batch	Test Date	LC50 with 95% Confidence Limits (mg/L Cu^{2+})	Previous Mean with 2SD (mg/L Cu^{2+})
AB180925	2018 Sep 25	0.98 (0.77, 1.25)	0.80 (0.33, 1.93)

2.4.2 Test Validity Criteria

The test is considered to be acceptable if the mean percent survival in the negative control is ≥70%, and the mean dry weight is ≥ 0.6 mg. The mean percent survival of the negative controls was 96%, and the mean dry weight was 1.9 mg.

2.5 Results

Total survival and dry weights in each replicate, and mean ± standard deviation (SD) in the control and test sediments are listed in the "*Chironomus dilutus* Survival and Growth Test- Survival of Larvae" and the "Chironomid Survival and Growth Test- Dry Weights of Larvae" data sheets, respectively. A summary of the test results is presented in Table 2-3.

Total ammonia concentrations, pH, temperature, dissolved oxygen, hardness, conductance, and alkalinity measurements of the overlying water at test initiation (Day 0) and completion (Day 10) are available in Appendix B.

2.5.1 Data Analysis

The survival and dry weights data for all samples and the negative control was entered into the statistical program "Comprehensive Environmental Toxicity Information System" (CETIS™, 2009-2016). When determining the appropriate comparison tests to use, the Environment Canada "Guidance Document on Statistical Methods for Environmental Toxicity Tests" (EPS 1/RM/46, 2005) was followed.

See the CETIS™ Analytical Reports for information on the specific tests used for the mean survival and dry weight comparisons. Analyses between the negative control and the samples were conducted as one-tailed comparisons. All analyses were done with the decision level for determining statistical significance set to 0.05 (p value <0.05).

Table 2-3 Results for Mean *Chironomus dilutus* Survival and Growth

Sample ID	Mean Survival ± SD (%)	Mean Dry Weight ± SD (mg)
Negative Control	96 ± 5	1.94 ± 0.16
PZ-1 (UD7929 – UD7933)	92 ± 11	2.01 ± 0.29
IC-1 (UD7934 – UD7938)	98 ± 4	2.00 ± 0.20
LZ-COMP (UD7947 – UD7951)	100 ± 0	2.20 ± 0.25

SD = Standard Deviation

There was no significant difference between any of the samples and the negative control.

2.6 Deviations and Observations

None.

SECTION

3 14 DAY *HYALELLA AZTECA* SURVIVAL AND GROWTH TEST

3.1 Test Methods

The survival and growth of the freshwater amphipod, *Hyalella azteca*, when exposed to whole sediment samples for 14 days, were assessed according to the Maxxam SOP: *Hyalella azteca* 14-Day Survival and Growth Test (BBY2SOP-00011), which is based on the Environment Canada Biological Test Method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca* (EPS 1/RM/33).

One day prior to test initiation, the field replicates were individually homogenised, and a 100 mL aliquot was distributed into a 375 mL labelled test vessel. Reconstituted moderately hard water was then slowly added to the vessel by pouring a stream of water onto a Plexiglas baffle to minimize disturbing the sediment layer. The test vessels were then randomized on the bench top, and airlines and lids were fitted to each test vessel.

A composite sample was produced by combining equal portions of each field replicate. Then, 100 mL of the composite sample was distributed into a sixth replicate test vessel used for water quality measurements.

The following day, aliquots of overlying water were removed from the test vessels for initial overlying water chemistry. The sixth replicate test vessel was used for water quality measurements for the duration of the test. To initiate the test, the amphipods were removed from their holding containers and ten *Hyalella* were randomly selected and placed into plastic medicine cups containing control water. Once enough organisms were collected to start the tests they were seeded into the test vessels.

During the test, daily observations and aeration checks were performed. Temperature and dissolved oxygen measurements were taken three times per week in the test vessel designated for water quality measurements. Test vessels were also fed 800 µL per replicate of a ground Tetramin™ flake slurry (4 g dry solids/L) and 1.75 mL YCT (yeast, alfalfa flakes, and digested trout chow) on the days the water quality measurements were taken.

At test termination, the contents of each test vessel were examined, a small portion at a time, in a glass pan on a light table. The live amphipods were collected and counted. The amphipods were then placed into aluminum foil weigh boats that were subsequently placed into a ~60°C drying oven for >24 hours. Missing amphipods were presumed to have died and decomposed during the test.

3.2 Organism Information

3.2.1 Acclimation and Holding Information

One batch of *Hyalella azteca* was received from Aquatic Biosystems, Fort Collins, Colorado, USA, on September 11, 2018. Laboratory reared juvenile amphipods were packed into 1L plastic containers, filled with moderately hard water and a few plastic mesh squares. Prior to shipping, the headspace in each container was filled with oxygen gas of a sufficient concentration to maintain adequate saturation levels in the shipping water. They were shipped directly for overnight delivery to Maxxam and arrived without incident.

Upon arrival at Maxxam, the container contents were carefully poured into glass culture dishes. Gentle aeration was supplied to each culture pan. An aliquot of shipping water from each container was set aside for water quality. It was then ensured that temperature adjustments to the holding water of the amphipods did not exceed 2°C per day.

The organisms were held at Maxxam for two days before the test was initiated. The amphipods were fed YCT and Tetramin™ slurry at organism arrival and before test initiation. Datasheets containing the water quality measurements, with observations of number dead or inactive amphipods during the holding period, are available in Appendix C.

3.2.2 Organism Health

The average mortality rate in the culture did not exceed 10%.

3.2.3 Organism Age

At test initiation, the amphipods were 7-9 days old.

3.3 Test Conditions

See Table 3-1 for a detailed list of the test conditions. All bench sheets and raw data are available in Appendix C.

Table 3-1 Test Conditions for the 14-day *Hyalella azteca* Test

Parameter	Conditions and Methods
Test Type and Duration	14 Day, Static
Temperature	Average daily temperature 23 ± 1 °C; instantaneous temperature 23 ± 3 °C.
Photoperiod and Light Intensity	16 hours light: 8 hours dark. Wide spectrum cool white fluorescent lights used to provide 603- 678 lux.
Aeration	< 100 bubbles/ minute. Clean oil-free air supplied to each test vessel via micro-bore plastic tubing.
Test Chamber	375 mL glass jars with plastic lids containing small opening for airline tubing.
Sediment Volume	100 mL of each homogenized field replicate (3-4 cm depth).
Overlying Water Volume and Source	175 mL (~5-6 cm depth); Reconstituted water; SAM5 recipe (Borgmann, 1996). Temperature adjusted and aerated >24h before use.
Overlying Water Quality	Temperature, pH, dissolved oxygen, conductance, hardness, alkalinity, and ammonia measurements on Day 0 and Day 14 of the test.
Feeding	800 µL of a ground Tetramin™ flake slurry (4g dry solids/mL), and 1.75 mL YCT per vessel, three times weekly.
Replicates	5 replicates per sample, plus an additional replicate for water quality measurements.
Control Sediment	Yaquina Bay beach sand rinsed with clean overlying water and sieved through a 500 µm stainless steel mesh.
Reference Sediment	None.
Organisms/ Replicate	10
Organism Source and age	Aquatic Biosystems; amphipods aged 7-9 days at test start.
Mortality during acclimation	0.0%
Endpoints	Mean Survival, Mean Dry weight
Test Validity Criteria	≥ 80% mean survival in the controls. ≥0.1 mg/amphipod in the controls.
Statistical Software	CETIS™ version 1.9.2.4. Tidepool Scientific Software (Copyright 2009-2016).

3.4 Quality Assurance/Quality Control

3.4.1 Reference Toxicant Results

A 96 hour reference toxicant test, or positive control test, was conducted alongside the sediment test. The water-only test, using copper sulphate ($CuSO_4$) was initiated to aid in the assessment of organism sensitivity and the precision of the results. The reference toxicant test LC50 result was then compared in a control chart against the results of previous tests. Table 3-2 summarises the result of the reference toxicant test.

The calculated LC50 for the reference toxicant test was within the two standard deviation (95%) range of the historic mean LC50. This supports the assumption that the sensitivity of organism batch was comparable to batches previously tested in this laboratory.

A reference toxicant test is only one of the tools used to assess the health of an organism. Natural variability accounts for the spread in reference toxicant LC50s. The method used in preparing the control charts was based on from "Ecotoxicology Control Charting" (COR2WI-00002).

Table 3-2 Reference Toxicant Test Results for *Hyalella azteca*

Organism Batch	Test Date	LC50 with 95% Confidence Limits (µg/L Cu^{2+})	Previous Mean with 2SD (µg/L Cu^{2+})
AB180911	2018 Sep 13	223 (191, 259)	240 (182, 316)

3.4.2 Test Validity Criteria

Survival data in the negative control is considered to be acceptable if the mean percent survival in the negative control is ≥80%, and the mean dry weight in the negative control is ≥0.1 mg/amphipod. The mean percent survival of the negative control was 100% and the mean dry weight was 0.2 mg/amphipod.

3.5 Results

Total survival and dry weights in each replicate, and mean ± standard deviation (SD) in the control and test sediments are listed in the "*Hyalella azteca* Survival and Growth Test-Survival" and "*Hyalella azteca* Survival and Growth Test- Dry Weights" data sheets, respectively. A summary of the results is located in Table 3-3.

Total ammonia concentrations, pH, temperature, dissolved oxygen, hardness, conductance, and alkalinity measurements in the overlying water at test initiation (Day 0) and completion (Day 14) are available in Appendix C.

3.5.1 Data Analysis

The survival and dry weight data for all samples and the negative control was entered into the statistical program "Comprehensive Environmental Toxicity Information System" (CETIS™, 2009-2016). When determining the appropriate comparison tests to use, the Environment Canada "Guidance Document on Statistical Methods for Environmental Toxicity Tests" (EPS 1/RM/46, 2005) was followed.

See the CETIS™ Analytical Reports for information on the specific tests used for the mean survival and dry weight comparisons. Analyses between the negative control and the samples were conducted as one-tailed comparisons. All analyses were done with the decision level for determining statistical significance set to 0.05 (p value <0.05).

Table 3-3 Results for Mean *Hyalella azteca* Survival and Growth

Sample ID	Mean Survival ± SD (%)	Mean Dry Weight ± SD (mg)
Negative Control	100 ± 0	0.21 ± 0.02
PZ-1 (UD7929 – UD7933)	90 ± 7	0.14 ± 0.02*
IC-1 (UD7934 – UD7938)	98 ± 4	0.24 ± 0.04
LZ-COMP (UD7947 – UD7951)	96 ± 9	0.23 ± 0.04

SD = Standard Deviation

*Indicates a statistically significant decrease in the sample relative to the negative control.

3.6 Deviations

None.

SECTION

4 REFERENCES

Borgmann, U. 1996. Systematic Analysis of Aqueous Ion Requirements of *Hyalella azteca*: A Standard Artificial Medium Including the Essential Bromide Ion. Archives of Environmental Contamination and Toxicology. 30: 356-363.

Comprehensive Environmental Toxicity Information System (CETIS™). 2009-2016. Tidepool Scientific. LLC. Version 1.9.2.4

Environment Canada. 1997. Biological Test method: Test for Survival and Growth in Sediment of Freshwater Midges (*Chironomus tentans or Chironomus riparius*). Environmental Protection Publications, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/32.

Environment Canada. 2005. Guidance Document on Statistical Methods for Environmental Toxicity Tests. Environmental Protection Publications. Conservation and Protection. Ottawa, Ontario. EPS 1/RM/46.

Environment Canada. 2013. Biological Test method: Test for Survival and Growth in Sediment and Water Using the Freshwater Amphipod *Hyalella azteca*. Environmental Protection Publications, Conservation and Protection. Ottawa, Ontario. EPS 1/RM/33.

Maxxam SOP for the *Chironomus dilutus* 10-Day Survival and Growth Test. BBY2SOP-00010.

Maxxam SOP for the *Hyalella azteca* 14-Day Survival and Growth Test. BBY2SOP-00011.

Maxxam WI for Ecotoxicology Control Charting. COR2 WI-00002.

APPENDICES

APPENDIX

A SAMPLE INFORMATION

ECOTOXICOLOGY
SEDIMENT SAMPLE DESCRIPTIONS

Client # / Name:11052 Hatfield

Job #:~~B857132~~ (A) B872132

Maxxam Sample Name	Sample #	Client Sample Name	Date Homogenised / Subsampled	Grain Size & Colour	Type of Debris Removed (e.g. rock, wood, plant, etc...)	Endemic Animals Removed	Odour	Additional Comments/Observations	Analyst
LZ-COMP	UD7947	LZ-COMP 1OF5	2018 sept12 2018 sep 13	brown sandy	~~NA~~ AW 2018 sept12 small rocks	small worms	NA	N/A	AW SR
LZ-COMP	UD7948 ~~UD7248~~ (A)	LZ-COMP 2OF5	2018 sept12 2018 sep 13	brown sandy	NA	NA	NA	N/A	AW SR
LZ-COMP	UD7949 ~~UD7249~~ (A)	LZ-COMP 3OF5	2018 sept12 2018 sep 13	brown sandy	small rock	NA	NA	NA	AW SR
LZ-COMP	UD7950 ~~UD7250~~ (A)	LZ-COMP 4OF5	sept12 2018 2018 sep 13	brown sandy	N/A	NA	N/A	NA	AW SR
LZ-COMP	UD7951 ~~UD7251~~ (A)	LZ-COMP 5OF5	2018 sept12 2018 sep 13	brown sandy	NA	NA	NA	NA	AW SR

N/A MT 2018 Oct 16

(A) WE MT 2018 Oct 16

ECOTOXICOLOGY

SEDIMENT SAMPLE DESCRIPTIONS

Client # / Name:11052 Hatfield

Job #:~~B857132~~ (A) B872132

Maxxam Sample Name	Sample #	Client Sample Name	Date Homogenised / Subsampled	Grain Size & Colour	Type of Debris Removed (e.g. rock, wood, plant, etc...)	Endemic Animals Removed	Odour	Additional Comments/Observations	Analyst
PZ-1	UD7929	PZ-1 1OF5	2018 sept12 2018 sep13	Brown Silty	~~small worms~~ AW 2018 sept12 N/A	small worms	N/A	N/A	AW SR
PZ-1	UD7930 ~~UD7230~~ (A)	PZ-1 2OF5	2018 sept12 2018 sep13	Brown Silty	N/A	small worms	N/A	N/A	AW SR
PZ-1	UD7931 ~~UD7231~~ (A)	PZ-1 3OF5	2018 sept12 2018 sep13	Silty brown	N/A	small worms	N/A	N/A	AW SR
PZ-1	UD7932 ~~UD7232~~ (A)	PZ-1 4OF5	2018 sep12 2018 sep13	brown silty	N/A	small worms	N/A	N/A	AW SR
PZ-1	UD7933 ~~UD7233~~ (A)	PZ-1 5OF5	2018 sep12 2018 sep13	brown silty	~~N/A~~ AW 2018 sept12 small rock	small worms	N/A	N/A	AW SR
IC-1	UD7934 ~~UD7234~~ (A)	IC-1 1OF5	2018 Sept12 2018 Sep13	brown sandy	n/a	n/a	n/a	n/a	DMc mo
IC-1	UD7935 ~~UD7235~~ (A)	IC-1 2OF5	2018 Sept12 2018 Sep13	brown sandy	n/a	n/a	n/a	n/a	DMc mo
IC-1	UD7936 ~~UD7236~~ (A)	IC-1 3OF5	2018 Sept12 2018 Sep13	brown sandy	n/a	n/a	n/a	n/a	DMc mo
IC-1	UD7937 ~~UD7237~~ (A)	IC-1 4OF5	2018 Sept12 2018 Sep13	brown sandy	n/a	n/a	n/a	n/a	DMc mo
IC-1	UD7938 ~~UD7238~~ (A)	IC-1 5OF5	2018 Sept12 2018 Sep13	brown sandy	n/a	n/a	n/a	n/a	mo DMc

(A) WE MH 2018 Oct16

ECOTOXICOLOGY
SEDIMENT SAMPLE DESCRIPTIONS

Client # / Name: 11052, Hatfield

Job #: ~~B857132~~ B872132 (A)

Maxxam Sample Name	Sample #	Client Sample Name	Date Homogenised / Subsampled	Grain Size & Colour	Type of Debris Removed (e.g. rock, wood, plant, etc...)	Endemic Animals Removed	Odour	Additional Comments/Observations	Analyst
PZ-1	(A) UD7929 ~~UD7229~~	PZ-1 1 OF5	2018 Sep 24	Brown, Silty	no	no	no	n/a	GS
PZ-1	(A) UD7930 ~~UD7230~~	PZ-1 2 OF5	2018 Sep 24	Brown, Silty	no	no	no	n/a	GS
PZ-1	(A) UD7931 ~~UD7231~~	PZ-1 3OF5	2018 Sep 24	Brown, Silty	no	no	no	n/a	GS
PZ-1	(A) UD7932 ~~UD7232~~	PZ-1 4OF5	2018 Sep 24	Brown, Silty	no	no	no	n/a	GS
PZ-1	(A) UD7933 ~~UD7233~~	PZ-1 5OF5	2018 Sep 24	Brown, Silty	no	no	no	n/a	GS
IC-1	(A) UD7934 ~~UD7234~~	IC-1 1OF5	2018 Sep 24	Dark grey, Sandy	no	no	no	n/a	GS
IC-1	(A) UD7935 ~~UD7235~~	IC-1 2OF5	2018 Sep 24	Grey, Sandy	no	no	no	n/a	GS
IC-1	(A) UD7936 ~~UD7236~~	IC-1 3OF5	2018 Sep 24	Grey, Sandy	no	no	no	n/a	GS
IC-1	(A) UD7937 ~~UD7237~~	IC-1 4OF5	2018 Sep 24	Grey, Sandy	no	no	no	n/a	GS
IC-1	(A) UD7938 ~~UD7238~~	IC-1 5OF5	2018 Sep 24	Grey, Sandy	no	no	no	n/a	GS

(A) WE MH 2018 Oct 16

ECOTOXICOLOGY

SEDIMENT SAMPLE DESCRIPTIONS

Client # / Name: 11052, Hatfield

Job #: (A) ~~B857132~~ B872132

Maxxam Sample Name	Sample #	Client Sample Name	Date Homogenised / Subsampled	Grain Size & Colour	Type of Debris Removed (e.g. rock, wood, plant, etc...)	Endemic Animals Removed	Odour	Additional Comments/Observations	Analyst
LZ-COMP (A)	~~UD7247~~ UD7947	LZ-COMP 1 OF5	2018 Sep 24	Brown, Sandy	no	no	no	n/a	GJ
LZ-COMP (A)	~~UD7248~~ UD7948	LZ-COMP 2 OF5	2018 Sep 24	Brown, Sandy	no	no	no	n/a	GJ
LZ-COMP (A)	~~UD7249~~ UD7949	LZ-COMP 3OF5	2018 Sep 24	Brown, Sandy	no	no	no	n/a	GJ
LZ-COMP (A)	~~UD7250~~ UD7950	LZ-COMP 4OF5	2018 Sep 24	Brown, Sandy	no	no	no	n/a	GJ
LZ-COMP (A)	~~UD7251~~ UD7951	LZ-COMP 5OF5	2018 Sep 24	Brown, Sandy	no	no	no	n/a	GJ

N/A MT 2018 Oct 16

(A) WE MT 2018 Oct 16.

ECOTOXICOLOGY
FRESHWATER SEDIMENT TESTS – POREWATER MEASUREMENTS

Client # & Name: 11052- Hatfield   Date Measured: 2018 Sep25

Method for Porewater Collection:
poured off overly, mixed sediment, spun in centrifuge bottles for 20 min at 5000 rpm, 4°C.

Sample ID	Temperature (°C)	pH	Ammonia (mg/L) Ⓑ
ctrl porewater Day 0	18.8 ~~22.5~~ Ⓐ	7.9	✓ 0.56
PZ-P porewater Day 0	18.9	7.7	✓ 0.033
LZ-COMP porewater Day 0	17.8	7.8	✓ 0.13
IC-1 porewater Day 0	17.9	7.6	✓ 0.20
Analyst	S.Rostama	SR	SR
Date	2018 sep 25	2018 sep 25	2018 sep 25

N/A SR 2018 sep 25

Comments:

n/a   Ⓑ Ammonia values transcribed 2018 Oct16 by MH. MH 2018 Oct16.

N/A MH 2018 Oct16

Ⓐ WE SR 2018 sep 25

Maxxam
A Bureau Veritas Group Company

Success Through Science

Maxxam Job #: B883343
Report Date: 2018/10/03

Maxxam Analytics (TOX Internal)
Sampler Initials: NB

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UK2823	UK2824	UK2825	UK2826	
Sampling Date		2018/09/25 10:00	2018/09/25 10:00	2018/09/25 10:00	2018/09/25 10:00	
COC Number		9002	9002	9002	9002	
	UNITS	**LZ-COMP Porewater Day 0**	**PZ-1 Porewater Day 0**	**IC-1 Porewater Day 0**	**Control Porewater Day 0**	**RDL**
Nutrients						
Total Ammonia (N)	mg/L	0.13	0.033	0.20	0.56	0.020
RDL = Reportable Detection Limit						

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

s.19(1)

1017

Maxxam
A Bureau Veritas Group Company

Calgary: 4000 19th St. NE, T2E 6P8. Toll Free (800) 386-7247
Edmonton: 9331-48 St. T6B 2R4. Toll Free (800) 386-7247
maxxam.ca

CHAIN OF CUSTODY RECORD

Invoice Information		Report Information (if differs from invoice)		Project Information		Turnaround Time (TAT) Required
Company:	Hatfield Consultants	Company:		Quotation #:	563419	[X] 5 - 7 Days Regular (Most analyses)
Contact Name:	Chris Jaeggle, Andrew O'Gorman	Contact Name:		P.O. #/ AFE#:	CNUL9184	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Address:	Suite A, 300 MacKenzie Blvd	Address:				Rush TAT (Surcharges will be applied)
	Fort McMurray, AB, Canada			Project #:	CNUL9184	[ ] Same Day [ ] 2 Days
Phone:	780-743-4290	Phone:		Site Location:	CNUL Albian	[ ] 1 Day [ ] 3-4 Days
Email:	[redacted]	Email:		Site #:		Date Required:
Copies:		Copies:		Sampled By:	AO/AJ	Rush Confirmation #:

Laboratory Use Only

	YES	NO	Cooler ID			
Seal Present		✓	Temp	1	3	1 °C
Seal Intact		✓				
Cooling Media	✓					
	YES	NO	Cooler ID	MUAC		
Seal Present	✓		Temp	3	1	1
Seal Intact	✓					
Cooling Media	✓					
	YES	NO	Cooler ID			
Seal Present	✓		Temp	0	1	2
Seal Intact	✓					
Cooling Media	✓					

Depot Reception

Received in Fort McMurray
By: [signature]
AUG 24 2018
@10:47am

Analysis Requested

	Sample Identification	Depth (Unit)	Date Sampled (YYYY/MM/DD)	Time Sampled (HH:MM)	Matrix	# of containers	BTEX F1 [ ] VOC [ ]	BTEX F1-F2	BTEX F1-F4	Routine Water	Regulated Metals Tot [ ] Diss [ ]	Mercury Total [ ] Dissolved [ ]	Salinity 4	Sieve (75 micron)	Texture (% Sand, Silt, Clay)	Basic Class II Landfill	Sediment Toxicity	HOLD - DO NOT ANALYZE
1	PZ-1 1of5	11.5	2018-08-23	9:17	Sediment	1											x	
2	PZ-1 2of5	11.5	2018-08-23	9:17	Sediment	1											x	
3	PZ-1 3of5	11.5	2018-08-23	9:17	Sediment	1											x	
4	PZ-1 4of5	11.5	2018-08-23	9:17	Sediment	1											x	
5	PZ-1 5of5	11.5	2018-08-23	9:17	Sediment	1											x	
6																		
7																		
8																		
9																		
10																		

Temp

Regulatory Criteria

- [ ] AT1
- [ ] CCME
- [ ] Drinking Water
- [ ] D50 (Drilling Waste)
- [ ] Saskatchewan
- [ ] Other:

Special Instructions

Please indicate Filtered, Preserved or Both (F, P, F/P)

Relinquished by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)	Received by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)
X [redacted]	2018/08/24	10:45	[redacted]	2018/08/25	08:00

Unless otherwise agreed to in writing, work submitted on this Chain of Custody is subject to Maxxam's standard Terms and Conditions. Signing of this Chain of Custody document is acknowledgment and acceptance of our terms which are available for viewing at www.maxxam.ca/term

24-Aug-18 10:47
Geraldlyn Gouthro
B872132
IL4 INS-0003

AB FCD-00331/7

s.19(1)

Maxxam A Bureau Veritas Group Company

Calgary: 4000 19th St. NE, T2E 6P8. Toll Free (800) 386-7247
Edmonton: 9331-48 St. T6B 2R4. Toll Free (800) 386-7247
maxxam.ca

CHAIN OF CUSTODY RECORD

Invoice Information		Report Information (if differs from invoice)		Project Information		Turnaround Time (TAT) Required
Company:	Hatfield Consultants	Company:		Quotation #:	563419	[X] 5 - 7 Days Regular (Most analyses)
Contact Name:	Chris Jaeggle, Andrew O'Gorman	Contact Name:		P.O. #/ AFE#:	CNUL9184	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Address:	Suite A, 300 MacKenzie Blvd	Address:				Rush TAT (Surcharges will be applied)
	Fort McMurray, AB, Canada			Project #:	CNUL9184	[ ] Same Day [ ] 2 Days
Phone:	780-743-4290	Phone:		Site Location:	CNUL Albian	[ ] 1 Day [ ] 3-4 Days
Email:	[redacted]	Email:		Site #:		Date Required:
Copies:		Copies:		Sampled By:	AO/AJ	Rush Confirmation #:

Laboratory Use Only

	YES	NO	Cooler ID			
Seal Present		✓	Temp	1	3	1
Seal Intact		✓				
Cooling Media	✓					
	YES	NO	Cooler ID MCAC			
Seal Present	✓		Temp	3	1	1
Seal Intact	✓					
Cooling Media	✓					
	YES	NO	Cooler ID			
Seal Present	✓		Temp	0	1	2
Seal Intact	✓					
Cooling Media	✓					

Depot Reception
Received in Fort McMurray
By: [signature]
AUG 24 2018
@10:47am
Temp:

Analysis Requested / **Regulatory Criteria**: [ ] AT1 [ ] CCME [ ] Drinking Water [ ] D50 (Drilling Waste) [ ] Saskatchewan [ ] Other:

#	Sample Identification	Depth (Unit)	Date Sampled (YYYY/MM/DD)	Time Sampled (HH:MM)	Matrix	# of containers	BTEX F1 [ ] VOC [ ]	BTEX F1-F2	BTEX F1-F4	Routine Water	Regulated Metals Tot [ ] Diss [ ]	Mercury Total [ ] Dissolved [ ]	Salinity 4	Sieve (75 micron)	Texture (% Sand, Silt, Clay)	Basic Class II Landfill	Sediment Toxicity	HOLD - DO NOT ANALYZE	Special Instructions
1	IC-1 1of5	1.3	2018-08-23	15:10	Sediment	1											x		
2	IC-1 2of5	1.3	2018-08-23	15:10	Sediment	1											x		
3	IC-1 3of5	1.3	2018-08-23	15:10	Sediment	1											x		
4	IC-1 4of5	1.3	2018-08-23	15:10	Sediment	1											x		
5	IC-1 5of5	1.3	2018-08-23	15:10	Sediment	1											x		
6																			
7																			
8																			
9																			
10																			

Please indicate Filtered, Preserved or Both (F, P, F/P)

Relinquished by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)	Received by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)
[redacted]	2018/08/24	10:45	[redacted]	2018/08/25	08:00

Maxxam Job #
24-Aug-18 10:47
Geraldlyn Gouthro
B872132
IL4 INS-0003

AB FCD-00331/7

s.19(1)

Maxxam
A Bureau Veritas Group Company

Calgary: 4000 19th St. NE, T2E 6P8. Toll Free (800) 386-7247
Edmonton: 9331-48 St. T6B 2R4. Toll Free (800) 386-7247
maxxam.ca

CHAIN OF CUSTODY RECORD

Invoice Information	Report Information (if differs from invoice)	Project Information	Turnaround Time (TAT) Required
Company: Hatfield Consultants	Company:	Quotation #: 563419	[X] 5 - 7 Days Regular (Most analyses)
Contact Name: Chris Jaeggle, Andrew O'Gorman	Contact Name:	P.O. #/ AFE#: CNUL9184	PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS
Address: Suite A, 300 MacKenzie Blvd, Fort McMurray, AB, Canada	Address:	Project #: CNUL9184	Rush TAT (Surcharges will be applied): [ ] Same Day [ ] 2 Days [ ] 1 Day [ ] 3-4 Days
Phone: 780-743-4290	Phone:	Site Location: CNUL Albian	
Email:	Email:	Site #:	Date Required:
Copies:	Copies:	Sampled By: Ao / AJ	Rush Confirmation #:

Laboratory Use Only

	YES	NO	Cooler ID			
Seal Present		—	Temp	1	3	1 °C
Seal Intact		✓				
Cooling Media	✓					
	YES	NO	Cooler ID			
Seal Present	✓		Temp	3	1	1
Seal Intact	✓					
Cooling Media	✓					
	YES	NO	Cooler ID			
Seal Present	✓		Temp	0	1	2
Seal Intact	✓					
Cooling Media	✓					

Depot Reception
Received in Fort McMurray
By: [signature]
AUG 24 2018
@10:47am

Temp

Analysis Requested

#	Sample Identification	Depth (Unit)	Date Sampled (YYYY/MM/DD)	Time Sampled (HH:MM)	Matrix	# of containers	BTEX F1 [ ] VOC [ ]	BTEX F1-F2	BTEX F1-F4	Routine Water	Regulated Metals Tot [ ] Diss [ ]	Mercury Total [ ] Dissolved [ ]	Salinity 4	Sieve (75 micron)	Texture (% Sand, Silt, Clay)	Basic Class II Landfill	Sediment Toxicity	HOLD - DO NOT ANALYZE
1	LZ-Comp 1of5		2018-08-23	13:10	Sediment	1											x	
2	LZ-Comp 2of5		2018-08-23	13:10	Sediment	1											x	
3	LZ-Comp 3of5		2018-08-23	13:10	Sediment	1											x	
4	LZ-Comp 4of5		2018-08-23	13:10	Sediment	1											x	
5	LZ-Comp 5of5		2018-08-23	13:10	Sediment	1											x	
6																		
7																		
8																		
9																		
10																		

Please indicate Filtered, Preserved or Both (F, P, F/P)

Regulatory Criteria
- [ ] AT1
- [ ] CCME
- [ ] Drinking Water
- [ ] D50 (Drilling Waste)
- [ ] Saskatchewan
- [ ] Other:

Special Instructions

Relinquished by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)	Received by: (Signature/ Print)	DATE (YYYY/MM/DD)	Time (HH:MM)	Maxxam Job #
	2018/08/24	10:45		2018/08/25	08:00	B872132

Unless otherwise agreed to in writing, work submitted on this Chain of Custody is subject to Maxxam's standard Terms and Conditions. Signing of this Chain of Custody document is acknowledgment and acceptance of our terms which are available for viewing at www.maxxam.ca/terms

APPENDIX

B 10-DAY CHIRONOMUS DILUTUS SURVIVAL AND GROWTH TEST

CETIS Analytical Report

Report Date: 15 Oct-18 18:35 (p 1 of 1)
Test Code: CT-11052-0118 | 11-1830-5567

Chironomus 10-d Survival and Growth Sediment Test — **Maxxam**

Analysis ID:	04-2898-4711	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:31	**Analysis:**	STP 2xK Contingency Tables	**Official Results:**	Yes
Batch ID:	17-3027-9997	**Test Type:**	Survival-AF Growth	**Analyst:**	
Start Date:	25 Sep-18 15:01	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Reconstituted Water
Ending Date:	05 Oct-18 12:00	**Species:**	Chironomus dilutus	**Brine:**	Not Applicable
Duration:	9d 21h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Fisher Exact/Bonferroni-Holm Test

Sample I vs	Sample II	Test Stat	P-Type	P-Value	Decision(α:5%)
Negative Control	PZ-1	0.3389	Exact	1.0000	Non-Significant Effect
	IC-1	0.8788	Exact	1.0000	Non-Significant Effect
	LZ-COMP	1.0000	Exact	1.0000	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	1.965	2.708	0.8008	No Outliers Detected

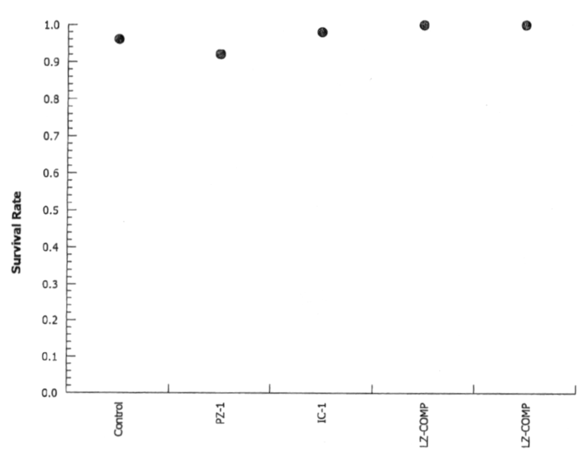
Data Summary

Group	Code	NR	R	NR + R	Prop NR	Prop R	%Effect
Control	N	48	2	50	0.96	0.04	0.0%
PZ-1		46	4	50	0.92	0.08	4.17%
IC-1		49	1	50	0.98	0.02	-2.08%
LZ-COMP		50	0	50	1	0	-4.17%

Survival Rate Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control	N	0.9000	1.0000	1.0000	1.0000	0.9000
PZ-1		0.8000	0.8000	1.0000	1.0000	1.0000
IC-1		1.0000	0.9000	1.0000	1.0000	1.0000
LZ-COMP		1.0000	1.0000	1.0000	1.0000	1.0000

Graphics



Analyst: 2018 Oct 15 [signature] QA: 2018 Oct 16 MH

Chironomus 10-d Survival and Growth Sediment Test — **Maxxam**

Analysis ID:	18-1151-2994	**Endpoint:**	Mean Dry Weight	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:32	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes
Batch ID:	17-3027-9997	**Test Type:**	Survival-AF Growth	**Analyst:**	
Start Date:	25 Sep-18 15:01	**Protocol:**	EC/EPS 1/RM/32	**Diluent:**	Reconstituted Water
Ending Date:	05 Oct-18 12:00	**Species:**	Chironomus dilutus	**Brine:**	Not Applicable
Duration:	9d 21h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Data Transform	Alt Hyp	Comparison Result	PMSD
Untransformed	C > T	PZ-1 passed mean dry weight	16.59%
		IC-1 passed mean dry weight	16.59%
		LZ-COMP passed mean dry weight	16.59%

Dunnett Multiple Comparison Test

Sample I vs	Sample II	Test Stat	Critical	MSD	DF	P-Type	P-Value	Decision(α:5%)
Negative Control	PZ-1	-0.4869	2.227	0.321	8	CDF	0.8887	Non-Significant Effect
	IC-1	-0.4445	2.227	0.321	8	CDF	0.8795	Non-Significant Effect
	LZ-COMP	-1.8	2.227	0.321	8	CDF	0.9949	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.024	2.708	0.6738	No Outliers Detected

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.188224	0.0627414	3	1.206	0.3393	Non-Significant Effect
Error	0.832066	0.0520041	16			
Total	1.02029		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance Test	1.506	11.34	0.6808	Equal Variances
Distribution	Shapiro-Wilk W Normality Test	0.9546	0.866	0.4417	Normal Distribution

Mean Dry Weight Summary

Group	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
Control	N	5	1.936	1.743	2.13	1.944	1.713	2.136	0.0697	8.05%	0.00%
PZ-1		5	2.006	1.65	2.363	1.854	1.78	2.43	0.1285	14.32%	-3.63%
IC-1		5	2	1.757	2.243	1.974	1.831	2.331	0.08746	9.78%	-3.31%
LZ-COMP		5	2.196	1.884	2.507	2.312	1.881	2.454	0.1122	11.42%	-13.41%

Mean Dry Weight Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control	N	1.883	1.944	1.713	2.005	2.136
PZ-1		2.43	1.79	1.854	2.178	1.78
IC-1		2.331	1.974	1.882	1.983	1.831
LZ-COMP		2.454	2.354	2.312	1.881	1.978

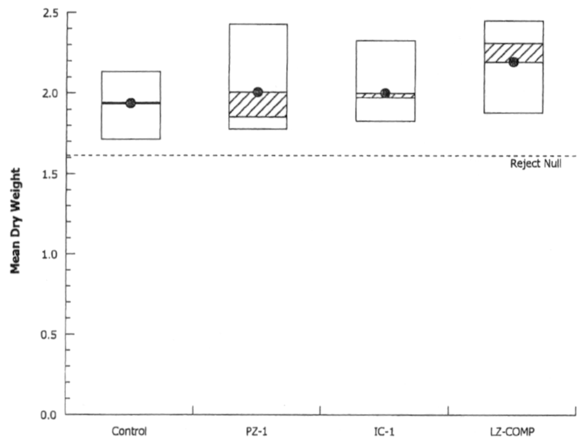
2018 Oct 15 Analyst: DM

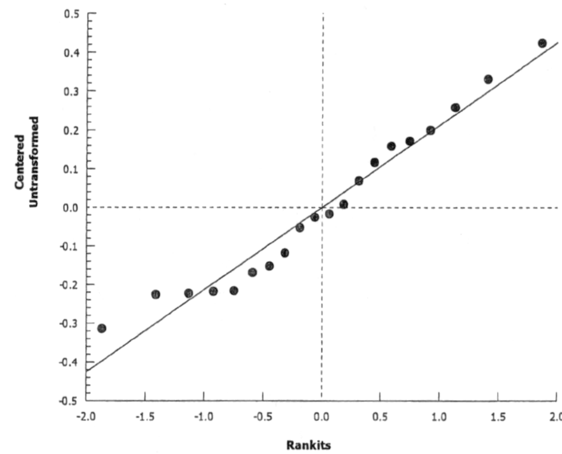
2018 Oct 16 QA: MT

Chironomus 10-d Survival and Growth Sediment Test **Maxxam**

Analysis ID:	18-1151-2994	**Endpoint:**	Mean Dry Weight	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:32	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes

Graphics





ECOTOXICOLOGY

Chironomus dilutus Survival and Growth Test
Survival of Larvae

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00271/3

Client # & Name: 11052 Hatfield

Start Date and Time: 2018 Sept 25 @ 15:01

Job # B872132

End Date: 2018 Oct 05

Organism Lot #: AB180925

Analysts: S. Rostama, G. Matharu

Sample	Rep	Initial # Larvae	Final # Larvae	% Survived	Survival	
					Mean %	SD %
Control	A	10	9	90	96	5
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	9	90		
PZ-1	A	10	8	80	92	11
	B	10	8	80		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		
IC-1	A	10	10	100	98	4
	B	10	9	90		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		
LZ-COMP	A	10	10	100	100	0
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		

Proofed: MH 2018 Oct 16

Maxxam

ECOTOXICOLOGY

Chironomid Survival and Growth Test
Dry Weights of Larvae

BBY2FCD-00231/3

Client # & Name: 11052-Hatfeild Consultants
Balance ID: BBY2-0260
Job # B872132
Drying Temperature (°C): 60
Analyst(s): [redacted] D. Lai

Start Date and Time: 2018 Sept 25
End Date: 2018 Oct 05
Weighing Dates: 2018 Sept 25 2018 Oct 15
Drying Time (h) >24

Boat #	Sample ID	Replicate	# Worms	Boat Wt. (g)	Boat & Worms Wt. (g)	Worm Wt. (mg)	Mean Wt. /Worm (mg)	Mean Wt. /Sample (mg)	SD
445	Control	A	9	1.10335	1.12030	16.95	1.88	1.94	0.16
446		B	10	1.12448	1.14392	19.44	1.94		
447		C	10	1.08261	1.09974	17.13	1.71		
448		D	10	1.09257	1.11262	20.05	2.00		
449		E	9	1.08090	1.10012	19.22	2.14		
450	PZ-1	A	8	1.09090	1.11034	19.44	2.43	2.01	0.29
451		B	8	1.10570	1.12002	14.32	1.79		
452		C	10	1.09303	1.11157	18.54	1.85		
453		D	10	1.10264	1.12442	21.78	2.18		
454		E	10	1.09269	1.11049	17.80	1.78		
455	IC-1	A	10	1.09950	1.12281	23.31	2.33	2.00	0.20
456		B	9	1.10781	1.12558	17.77	1.97		
457		C	10	1.10765	1.12647	18.82	1.88		
458		D	10	1.09090	1.11073	19.83	1.98		
459		E	10	1.08957	1.10788	18.31	1.83		
460	LZ-COMP	A	10	1.10477	1.12931	24.54	2.45	2.20	0.25
461		B	10	1.09828	1.12182	23.54	2.35		
462		C	10	1.08460	1.10772	23.12	2.31		
463		D	10	1.08172	1.10053	18.81	1.88		
464		E	10	1.09250	1.11228	19.78	1.98		
466CH	[redacted]	QA/QC		1.14956	1.14942	-	-	-	-
465		QA/QC		1.11381	1.11398	-	-	-	-
445		0-A	9	1.10350	1.12029	16.79	-	-	-
		Analyst:		AW	DML				

The average dry weight for the replicate controls must be >0.6 mg, for the test to be valid.

Notes:

Maxxam
A Bureau Veritas Group Company

ECOTOXICOLOGY
CHIRONOMUS DILUTUS SURVIVAL AND GROWTH TEST - TEST INFORMATION

Client # & Name: 11052 - Hatfield

Job #: B872132

Test Initiation Date & Time: 2018 Sept 25 @ 15:01 **Analyst:** NB

Test Completion Date: 2018 Oct 05

Analyst(s) - maintenance and test completion: N Blassnitz; S. Rostema; T. Wollelo, [signature] A Mathar, [redacted]

Control Water Batch: 2018 Sept 22

Control Sediment: Yaquina Bay beach sand

N/A MT 2018 Oct 16

Organism Lot: AB180925

Age at Start of Test: 3rd ~~2nd~~ Instar (A)

Feeding Regime: 3.75 mL Tetrafin slurry (4 g/L) per replicate 3x weekly

Food Preparation Date: 2018 Sept 25, 2018 Sep 17

Balance ID: BBY2-0260

Drying Oven ID: BBY2-0278

WQ Instrument ID: BBY2-0352, BBY2-0368

Additional Comments: N/A MT 2018 Oct 16

(A) WE MT 2018 Oct 16

ECOTOXICOLOGY
***CHIRONOMUS DILUTUS* TEST DATA SHEET**

Sample ID: CONTROL
Sample Date: N/A
Sample Received: N/A
Start Date: 2018 Sep 25
End Date: 2018 Oct 05
Job/Sample #: N/A

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity Ⓑ (mg/L $CaCO_3$)		Ammonia Ⓑ (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.2	8.5	88	112	390	567	✓ 59.6	✓ 140	✓ 0.17	✓ 0.70

Initial overlying WQ measurements:	
Analyst NB	Date 2018 Sep 25

Final overlying WQ measurements:	
Analyst S. Rostami	Date 2018 Oct 05

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.6	Ⓐ ~~22~~ 23.2	22.3	22.4	23.4
D.O. (mg/L)	8.4	8.4	8.6	8.7	8.4
Feeding	✓	✓	✓	✓	
Analyst	NB	TW	NB	SR	SR

Ⓑ values transcribed by MH on 2018 Oct 16
MH 2018 Oct 16

Replicate	A	B	C	D	E
# Surviving	9	10	10	10	9
Analyst	SR	SR	SR	SR	SR

Ⓐ WE TW 2018 Sep 28

Date	Replicate	Comments	Analyst
		N/A MH 2018 Oct 16	

ECOTOXICOLOGY
***CHIRONOMUS DILUTUS* TEST DATA SHEET**

Sample ID:	P2-1	Start Date:	2018 Sept 25
Sample Date:	2018 Aug 23	End Date:	2018 Oct 05
Sample Received:	2018 Aug 24	Job/Sample #:	B872132/UD7929

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity Ⓐ (mg/L $CaCO_3$)		Ammonia Ⓐ (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.2	8.4	160	200	369	510	✓ 72.1	✓ 123	✓ <0.020	0.049 ✓

Initial overlying WQ measurements:	
Analyst NB	Date 2018 Sept 25

Final overlying WQ measurements:	
Analyst S.Rostami	Date 2018 OCT 05

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.3	23.4	23.0	23.0	23.6
D.O. (mg/L)	8.5	8.3	8.4	8.5	8.4
Feeding	✓	✓	✓	✓	
Analyst	NB	TW	NB	SR	SR

Ⓐ values transcribed by MT 2018 Oct 16

Replicate	A	B	C	D	E
# Surviving	8	8	10	10	10
Analyst	SR	SR	SR	SR	SR

Date	Replicate	Comments	Analyst
		N/A MT 2018 Oct 16	

ECOTOXICOLOGY
CHIRONOMUS DILUTUS TEST DATA SHEET

Sample ID: IC-1
Sample Date: 2018 Aug 23
Sample Received: 2018 Aug 24

Start Date: 2018 Sep 25
End Date: 2018 Oct 05
Job/Sample #: B872132 / UD7934

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (B) (mg/L $CaCO_3$)		Ammonia (B) (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.3	8.5	128	208	391	546	✓ 92.3	✓ 155	✓ 0.38	✓ 0.43

Initial overlying WQ measurements:	
Analyst NB	Date 2018 Sept 25

Final overlying WQ measurements:	
Analyst S. Rostama	Date 2018 Oct 05

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.5	23.3	22.8	(A) ~~20~~ 22.7	23.4
D.O. (mg/L)	8.5	8.4	8.4	8.5	8.4
Feeding	✓	✓	✓	✓	
Analyst	NB	TW	NB	SR	SR

(A) WESR 2018 Oct 02

(B) values transcribed by MT 2018 Oct 16

Replicate	A	B	C	D	E
# Surviving	10	9	10	10	10
Analyst	SR	SR	CS	CS	CS

Date	Replicate	Comments	Analyst
		N/A MT 2018 Oct 16	

ECOTOXICOLOGY

***CHIRONOMUS DILUTUS* TEST DATA SHEET**

Sample ID: LZ-COMP
Sample Date: 2018 Aug 23
Sample Received: 2018 Aug 24

Start Date: 2018 Sep 25
End Date: 2018 Oct 05
Job/Sample #: B872132 / UD7947

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity Ⓐ (mg/L $CaCO_3$)		Ammonia Ⓐ (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.3	8.5	132	200	403	562	✓ 85.5	✓ 177	✓ 0.22	✓ 0.91

Initial overlying WQ measurements:	
Analyst NB	Date 2018 Sept 25

Final overlying WQ measurements:	
Analyst S. Rostama	Date 2018 Oct 05

Day	Tuesday Day 0	Friday Day 3	Sunday Day 5	Tuesday Day 7	Friday Day 10
Temp. (ºC)	23.6	23.3	23.1	22.8	23.5
D.O. (mg/L)	8.5	8.3	8.3	8.5	8.4
Feeding	✓	✓	✓	✓	
Analyst	NB	TW	NB	SR	SR

Ⓐ values transcribed by MT 2018 Oct 16.

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	10
Analyst	GS	GS	GS	GS	GS

Date	Replicate	Comments	Analyst
		N/A MT 2018 Oct 16	

ECOTOXICOLOGY
CHIRONOMID SURVIVAL AND GROWTH TEST – AERATION CHECKS

Client # & Name: 11052, Hatfield Start Date & Time: 2018 Sep 25 @ 15:01

Initial when aeration is checked. If air is off record DO and note which replicate(s) in comments section.

	Day -1	Day 0	1	2	3	4	5	6	7	8	9	10
Date	2018 Sep 24	2018 Sept 25	2018 sept 26	2018 sep 27	2018 sep 28	2018 SEP 29	2018 Sep 30	2018 Oct 01	2018 Oct 02	2018 Oct 03	2018 Oct 04	2018 Oct 05
Early AM	MA	NB	SR	SR	SR		NB	SR	SR	SR	mo	SR
Mid-day	CJ	NB	SR	SR	SR		NB	SR	SR	SR	mo	SR
Late PM	NB	NB	SR	SR	TW		NB	CJ	SR	SR	mo	MA

Comments:

2018 Sep 24 – Started aeration in all reps @ 13:10 – CJ

N/A MH 2018 Oct 16

Reconstitued Water Recipe for Chironomus

BATCH ID : 2018 Sep 22
(Date Hardened)

Chironomus dilutus **H_2O Hardness Adjustment (Environment Canada 1997)**
(For water hardness 90 - 100 mg/L)

Chemical Weights	$CaCl_2X2H_2O$	$MgSO_4$ (g)	$CaSO_4$ (g)	$NaHCO_3$ (g)	KCl (g)
Brand	Fisher	Fisher	Alfa Aesar	Fisher	Fisher
Lot #	171431	171687	~~D307~~ Ⓐ D307035	177037	149363
Calculated	2.65	1.20	2.00	3.84	0.16
Actual	2.6504	1.2004	2.0001	3.8401	0.1600

Balance ID: BBY2-0260

Analyst: T. Wollelo

Add to Type 3 DI (L): 40

Water Use: 11052

DI Machine ID: BBY2-0159

Date: 2018 Sept 22

Water Quality:

Temp: 23.4 pH: 8.1 Hardness 96

Cond.: 347 DO: 8.6 Alkalinity: n/a

Analyst: C Mathew Date: 2018 Sep 24

Comments: BBY2-0366

CaCl2 x 2H2O (Calcium Chloride - dihydrous)

MgSO4 (Magnesium Sulphate - anhydrous)

$CaSO_4$ (g) (Calcium Sulphate- anhydrous)

NaHCO3 (Sodium Bicarbonate)

KCl (Potassium Chloride)

Recipe: 0.45mM CaCl2: 0.37mM CaSO4: 0.25mM MgSO4: 1.14mM NaHCO3: 0.05mM KCl

Ⓐ WETW 2018 Sep 24

ECOTOXICOLOGY

Chironomus dilutus (Formerly C. tentans)
Measurements of Head Capsule Widths

Maxxam

BBY2FCD-00247/1

Client # & Name: 11052 - Hatfield Consultants

Start Date and Time: 2018 Sep 25 @ 15:01

End Date: 2018 Oct 05

Organism Lot #: AB180925CH

Head Widths at Beginning of Test

Chironomid #	Head Width (mm)
1	0.35
2	0.35
3	0.35
4	0.35
5	0.19
6	0.40
7	0.33
8	0.30
9	0.30
10	0.35
11	0.34
12	0.39
13	0.36
14	0.39
15	0.33
16	0.37
17	0.40
18	0.35
19	0.33
20	0.35
Average	0.34
SD	0.05
Analyst	DML

Average must be 0.33-0.45 mm (Environment Canada 1998)
1 mm=40 units on micrometer

Proofed: mt 2018 Oct 16

ECOTOXICOLOGY

Chironomus dilutus (Formerly C. tentans)
Measurements of Head Capsule Widths

Maxxam

BBY2FCD-00247/1

Client # & Name: Hatfield.

Start Date and Time: 2018 Sept25

End Date: 2018

Organism Lot #: AB180925

Head Widths at Beginning of Test

Chironomid #	Head Width (mm)
1	0.35
2	0.35
3	0.35
4	0.35
5	0.19
6	0.40
7	0.33
8	0.30
9	0.30
10	0.35
11	0.34
12	0.39
13	0.36
14	0.39
15	0.33
16	0.37
17	0.40
18	0.35
19	0.33
20	0.35
Average	#DIV/0!
SD	#DIV/0!
Analyst	D Lai

200uM=20c
100uM=10c
0.1m=10c

Average must be 0.33-0.45 mm (Environment Canada 1998)
1 mm=40 units on micrometer

ORGANISMS - ACCLIMATION AND HOLDING CONDITIONS

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00070/5

Client #'s : 11052

Date & Time of Arrival: 2018 Sep 25 @ 11:40

Organism Lot #: AB180925CH

Age upon Arrival: Ⓐ ~~2nd~~ 3rd Instar

Water (L) per Shipping Bag: ~ 1 l

Organism: chironomus dilutus

Number of Shipping Bags: 4

#of Organisms Ordered: 500

Light Intensity (lux): 603 678

Arrival Conditions

Bag ID	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	Analyst
A	0	0	490	21.0	16.0	7.2	N/A	SR
B	0	0	506	22.3	12.3	7.0	N/A	SR
C	0	0	496	22.4	15.4	7.1	N/A	SR
D	0	0	494	21.6	20.3	7.1	N/A.	SR

N/A SR 2018 Sep 25

Daily Conditions During Holding/Acclimation

Date	Mortalities		Water Quality					Analyst
	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	
Total Mortalities								

N/A MT 2018 Oct 16

Equipment ID: BBY2-0352

Comments (e.g. feeding times and quantities; fish behaviour, acclimation conditions): | Analyst

n/a | SR

N/A MT 2018 Oct 16

Ⓐ WE MT 2018 Oct 16

AB180925CH

1300 Blue Spruce Drive, Suite C
Fort Collins, Colorado 80524

AQUATIC BIO SYSTEMS INC.
ABS

Toll Free: 800/331-5916
Tel:970/484-5091 Fax:970/484-2514

ORGANISM HISTORY

DATE: 9/24/2018

SPECIES: *Chironomus dilutus (formerly C. tentans)*

AGE: Deposited 9/15/2018 To Hatch 9/7/2017

LIFE STAGE: Second Instar 9/26/2018

HATCH DATE: Emergent date 10/9/2018

BEGAN FEEDING: Immediately

FOOD: *Raphidocelis subcapitata*.*, Flake slurry

Water Chemistry Record:	**Current**	**Range**
TEMPERATURE:	25°C	23-26°C
SALINITY/CONDUCTIVITY:	--	--
TOTAL HARDNESS (as $CaCO_3$):	138 mg/l	88-172 mg/l
TOTAL ALKALINITY (as $CaCO_3$):	100 mg/l	65-110 mg/l
pH:	8.16	7.50-8.28

Comments: * Formerly known as *Psuedokirschneriella subcapitata* and *Selenastrum capricornutum*

Facility Supervisor

Test: Chironomids

Start Date: 2018 Sep 25

Client # & Name: 11052-Hatfield

Back Wall	Position Map		
6	12	18	
5	11	17	
4	10	16	
3	9	15	
2	8	14	
1	7	13	etc.

Front of Counter

Position #	Sample ID	Replicate	Colour
19	Negative Control	A	Red
10		B	
13		C	
20		D	
23		E	
12		Measure	
9	PZ-1 1OF5	A	Orange
3		B	
8		C	
11		D	
16		E	
21		Measure	
18	IC-1 1OF5	A	Purple
22		B	
5		C	
1		D	
4		E	
14		Measure	
17	LZ-COMP 1OF5	A	Dark Green
24		B	
2		C	
15		D	
6		E	
7		Measure	

Position #	Sample ID	Replicate	Colour
37		A	Pink
38		B	
39		C	
40		D	
41		E	
42		Measure	
43		A	White
44		B	
45		C	
46		D	
47		E	
48		Measure	
49		A	Light Blue
50		B	
51		C	
52		D	
53		E	
54		Measure	
55		A	Light Green
56		B	
57		C	
58		D	
59		E	
60		Measure	

N/A NB 2018 Sept 25

Maxxam
A Bureau Veritas Group Company

Success Through Science

Maxxam Job #: B883343
Report Date: 2018/10/03

Maxxam Analytics (TOX Internal)
Sampler Initials: NB

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UK2819	UK2820	UK2821	UK2822	
Sampling Date		2018/09/25 10:00	2018/09/25 10:00	2018/09/25 10:00	2018/09/25 10:00	
COC Number		9002	9002	9002	9002	
	UNITS	Control Overly Day 0 CH	PZ-1 Overly Day 0 CH	IC-1 Overly Day 0 CH	LZ Comp Overly Day 0 CH	RDL
Misc. Inorganics						
Alkalinity (Total as CaCO3)	mg/L	59.6	72.1	92.3	85.5	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	72.7	88.0	113	104	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Nutrients						
Total Ammonia (N)	mg/L	0.17	<0.020	0.38	0.22	0.020
RDL = Reportable Detection Limit						

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Maxxam Job #: B887420
eport Date: 2018/10/12

Maxxam Analytics (TOX Internal)
Sampler Initials: SR

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UM5474	UM5475	UM5476	UM5477	
Sampling Date		2018/10/05	2018/10/05	2018/10/05	2018/10/05	
COC Number		9230	9230	9230	9230	
	UNITS	Control-Day 10 Overly Water	PZ1-Day 10 Overly Water	IC1-Day 10 Overly Water	LZ COMP-Day 10 Overly Water	RDL
Misc. Inorganics						
Alkalinity (Total as CaCO3)	mg/L	140	123	155	177	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	170	150	189	216	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Nutrients						
Total Ammonia (N)	mg/L	0.70	0.049	0.43	0.91	0.020
RDL = Reportable Detection Limit						

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

APPENDIX

C 14-DAY *HYALELLA AZTECA* SURVIVAL AND GROWTH TEST

CETIS Analytical Report

Test Code: HA-11052-0118 | 07-5345-7463

Hyalella 14-d Survival and Growth Sediment Test — **Maxxam**

Analysis ID:	08-9460-1835	**Endpoint:**	Survival Rate	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:47	**Analysis:**	STP 2xK Contingency Tables	**Official Results:**	Yes

Batch ID:	03-7881-1713	**Test Type:**	Survival-Growth	**Analyst:**	
Start Date:	13 Sep-18 15:26	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Reconstituted Water
Ending Date:	27 Sep-18 12:00	**Species:**	Hyalella azteca	**Brine:**	Not Applicable
Duration:	13d 21h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Fisher Exact/Bonferroni-Holm Test

Sample I vs	Sample II	Test Stat	P-Type	P-Value	Decision(α:5%)
Negative Control	PZ-1	0.0281	Exact	0.0844	Non-Significant Effect
	IC-1	0.5000	Exact	0.5000	Non-Significant Effect
	LZ-COMP	0.2475	Exact	0.4949	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.819	2.708	0.0285	Outlier Detected

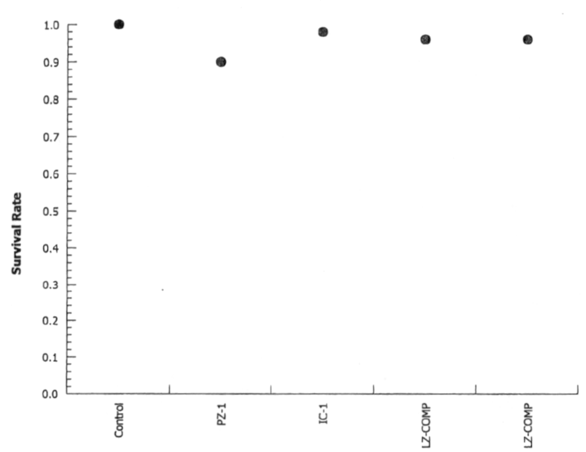
Data Summary

Group	Code	NR	R	NR + R	Prop NR	Prop R	%Effect
Control	N	50	0	50	1	0	0.0%
PZ-1		45	5	50	0.9	0.1	10.0%
IC-1		49	1	50	0.98	0.02	2.0%
LZ-COMP		48	2	50	0.96	0.04	4.0%

Survival Rate Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control	N	1.0000	1.0000	1.0000	1.0000	1.0000
PZ-1		1.0000	0.9000	0.9000	0.8000	0.9000
IC-1		1.0000	1.0000	1.0000	0.9000	1.0000
LZ-COMP		1.0000	1.0000	1.0000	1.0000	0.8000

Graphics



Analyst: 2018 Oct 15 DM QA: 2018 Oct 16 MH

Hyalella 14-d Survival and Growth Sediment Test — **Maxxam**

Analysis ID:	05-8306-9362	**Endpoint:**	Mean Dry Weight-mg	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:48	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes

Batch ID:	03-7881-1713	**Test Type:**	Survival-Growth	**Analyst:**	
Start Date:	13 Sep-18 15:26	**Protocol:**	EC/EPS 1/RM/33	**Diluent:**	Reconstituted Water
Ending Date:	27 Sep-18 12:00	**Species:**	Hyalella azteca	**Brine:**	Not Applicable
Duration:	13d 21h	**Source:**	Aquatic Biosystems, CO	**Age:**	

Data Transform	Alt Hyp	Comparison Result	PMSD
Untransformed	C > T	PZ-1 failed mean dry weight-mg	19.31%
		IC-1 passed mean dry weight-mg	19.31%
		LZ-COMP passed mean dry weight-mg	19.31%

Dunnett Multiple Comparison Test

Sample I vs	Sample II	Test Stat	Critical	MSD	DF	P-Type	P-Value	Decision(α:5%)
Negative Control	PZ-1*	3.743	2.227	0.040	8	CDF	0.0024	Significant Effect
	IC-1	-1.941	2.227	0.040	8	CDF	0.9965	Non-Significant Effect
	LZ-COMP	-1.059	2.227	0.040	8	CDF	0.9668	Non-Significant Effect

Auxiliary Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:5%)
Extreme Value	Grubbs Extreme Value Test	2.08	2.708	0.5689	No Outliers Detected

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	0.030975	0.010325	3	12.5	1.8E-04	Significant Effect
Error	0.0132117	0.0008257	16			
Total	0.0441867		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Bartlett Equality of Variance Test	2.519	11.34	0.4718	Equal Variances
Distribution	Shapiro-Wilk W Normality Test	0.9598	0.866	0.5406	Normal Distribution

Mean Dry Weight-mg Summary

Group	Code	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
Control	N	5	0.2096	0.185	0.2342	0.212	0.183	0.238	0.008858	9.45%	0.00%
PZ-1		5	0.1416	0.1179	0.1653	0.1422	0.1144	0.1663	0.008543	13.49%	32.45%
IC-1		5	0.2449	0.2005	0.2892	0.2633	0.196	0.281	0.01598	14.60%	-16.83%
LZ-COMP		5	0.2289	0.1846	0.2731	0.227	0.174	0.2713	0.01593	15.56%	-9.18%

Mean Dry Weight-mg Detail

Group	Code	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Control	N	0.212	0.212	0.238	0.183	0.203
PZ-1		0.135	0.1144	0.1422	0.1663	0.15
IC-1		0.265	0.219	0.281	0.2633	0.196
LZ-COMP		0.245	0.174	0.227	0.227	0.2713

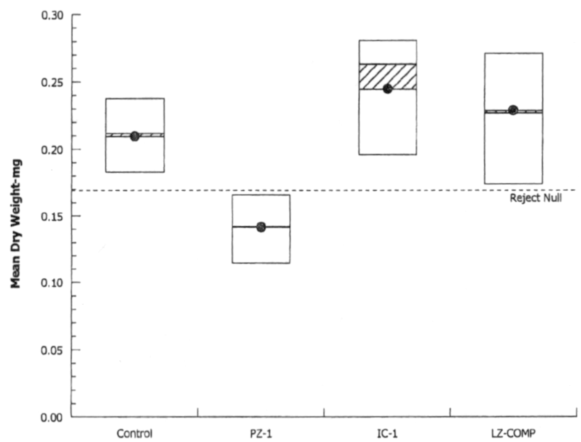
2018 Oct 16

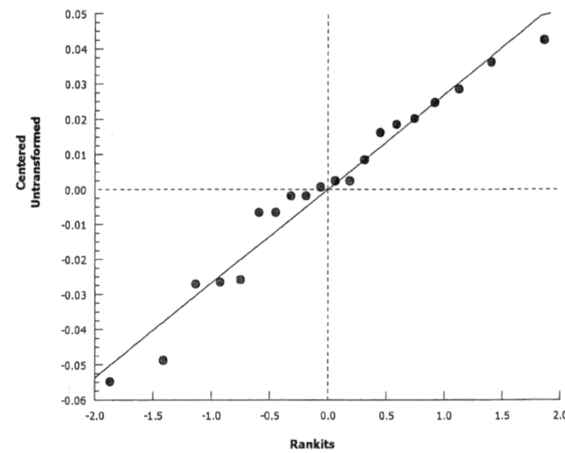
Analyst: 2018 Oct 15 [signature] QA: MH

Hyalella 14-d Survival and Growth Sediment Test **Maxxam**

Analysis ID:	05-8306-9362	**Endpoint:**	Mean Dry Weight-mg	**CETIS Version:**	CETISv1.9.2
Analyzed:	15 Oct-18 18:48	**Analysis:**	Parametric-Control vs Treatments	**Official Results:**	Yes

Graphics





ECOTOXICOLOGY

Hyalella azteca Survival and Growth Test - Survival

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00275/4

Client # & Name: 11502 Hatfield Consultants

Start Date and Time: 2018 Sep 13 @ 15:26

Job # B872132

End Date: 2018 Sep 27

Organism Lot #: AB180911

Analysts: S. Rostama

Sample	Rep	Initial # Hyalella	Final # Hyalella	% Survived	Survival Mean %	Survival SD %
Control	A	10	10	100	100	0
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	10	100		
PZ-1	A	10	10	100	90	7
	B	10	9	90		
	C	10	9	90		
	D	10	8	80		
	E	10	9	90		
IC-1	A	10	10	100	98	4
	B	10	10	100		
	C	10	10	100		
	D	10	9	90		
	E	10	10	100		
LZ-COMP	A	10	10	100	96	9
	B	10	10	100		
	C	10	10	100		
	D	10	10	100		
	E	10	8	80		

Proofed: mt 2018 oct16

s.19(1)

ECOTOXICOLOGY

Hyalella azteca Survival and Growth Test - Dry Weights

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00129/5

Client # & Name: 11052 Hatfield Consultants

Start Date and Time: 2018 Sep 13 @ 15:26

Job/Sample #: B872132/Various

End Date: 2018 Sep 27

Organism Lot #: AB180911

Drying Temperature (°C): 60 +/- 5

Weighing Dates: 2018 Oct 03

Drying Time (h): > 24 hours

Analysts: [redacted]

Boat #	Sample	Rep	# *Hyalella*	*Hyalella* Wt.(g)	*Hyalella* Wt. (mg)	Mean Wt./*Hyalella* (mg)	Mean Wt./Sample (mg)	SD
1	Control	A	10	0.00212	2.12	0.21	0.21	0.02
2		B	10	0.00212	2.12	0.21		
3		C	10	0.00238	2.38	0.24		
4		D	10	0.00183	1.83	0.18		
5		E	10	0.00203	2.03	0.20		
6	PZ-1	A	10	0.00135	1.35	0.14	0.14	0.02
7		B	9	0.00103	1.03	0.11		
8		C	9	0.00128	1.28	0.14		
9		D	8	0.00133	1.33	0.17		
10		E	9	0.00135	1.35	0.15		
11	IC-1	A	10	0.00265	2.65	0.27	0.24	0.04
12		B	10	0.00219	2.19	0.22		
13		C	10	0.00281	2.81	0.28		
14		D	9	0.00237	2.37	0.26		
15		E	10	0.00196	1.96	0.20		
16	LZ-COMP	A	10	0.00245	2.45	0.25	0.23	0.04
17		B	10	0.00174	1.74	0.17		
18		C	10	0.00227	2.27	0.23		
19		D	10	0.00227	2.27	0.23		
20		E	8	0.00217	2.17	0.27		
6		QA/QC	10	0.00138	1.38	0.14		
1		0 - A	10	0.00212	2.12	0.21		
		Analyst:	MT	MT				

The average dry weight for the replicate controls must be ≥0.1 mg, for the test to be valid.

Notes:

Maxxam
A Bureau Veritas Group Company

ECOTOXICOLOGY

HYALELLA AZTECA SURVIVAL AND GROWTH TEST - TEST INFORMATION

Client # & Name: 11052 Hatfield

Job #: B872132

Test Initiation Date & Time: 2018 Sept 13 @15:26

Test Completion Date: 2018 Sept 27

Room #: 103

Analyst(s): M.O'Toole, N.Shergill, N.Blassnitz, [signature]; S.Rostamnezhad, T.Wollelo, [redacted]

Control Water Batch: 2018 Sept 10

Control Sediment: Yaquina Bay beach sand

~~N/A MT 2018 Oct 16~~

Organism Lot: AB180911

Age at Start of Test: 7-9 days.

Feeding Regime: 1.75mL YCT & 800 µL tetramin slurry (4g/L) per replicate 3x weekly ✓

~~0.75 mL YCT & 340 µL tetramin slurry (4g/L) per replicate daily feeding~~ NB 2018 Sept 17 feeding 3x/week

YCT Batch Number: 2018 Sept 10, 2018 Sep 05,

Tetramin Preparation Date: 2018 Jul 03, 2018 Sep 14

Balance ID: BBY2-0421

Drying Oven ID: BBY2-0278.

WQ Instrument ID: BBY2-0368; BBY2-0368

Additional Comments: ~~N/A MT 2018 Oct 16~~

ECOTOXICOLOGY
HYALELLA AZTECA SURVIVAL AND GROWTH TEST - DATA SHEET

Sample ID: Control
Job #: B872132

Start Date: September 13, 2018
End Date: September 27, 2018

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity ⓓ (mg/L $CaCO_3$)		Ammonia ⓓ (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
7.8	8.1	140	140	431	~~458~~ 531 ⓒ	✓ 56.9	✓ 77.5	✓ <0.020	✓ 0.48

Initial overlying WQ measurements:	
Analyst N Shergill	Date 2018 Sept 13

Final overlying WQ measurements:	
Analyst S. Rostame	Date 2018 Sep 27

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Thursday Day 14
Temp. (ºC)	23.4	23.8	23.9	23.6	23.2	23.7	23.5
D.O. (mg/L)	8.6	8.5	Ⓐ ~~7~~ 8.3	8.4	8.4	8.4	8.3
Subsampled for ammonia (√)	✓						✓
Analyst	NS	J	TW	mo	SR	mo	SR

Feeding–Day:	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Analyst	NS	~~TW~~ n/a Ⓑ	~~TW~~ J Ⓑ	n/a	n/a	TW	n/a	mo	n/a	SR	n/a	n/a	mo	n/a

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	10
Analyst	SR	SR	SR	SR	SR

Ⓔ clearification: probe in wrong solution for measurment, remeasured conductivity SR 2018 Oct 22 L.E

Date	Replicate	Comments and/or additional WQ measurements:	Analyst
		N/A MT 2018 Oct 03	

ⓒ WE SR Ⓔ 2018 Sep 27 cond prob was not in correct place - SR

Ⓐ WE TW 2018 Sep 18
Ⓑ WE J 2018 Sep 19

ⓓ values transcribed by MT 2018 Oct 16.

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00143/6

Form: Sample

ECOTOXICOLOGY

HYALELLA AZTECA **SURVIVAL AND GROWTH TEST - DATA SHEET**

Sample ID: PZ-1 1OF5

Job #/Sample #: B872132 UD7929

Start Date: September 13, 2018

End Date: September 27, 2018

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (d) (mg/L $CaCO_3$)		Ammonia (d) (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
7.8	8.3	148	224	435	~~853~~ ~~458~~ 556 (B)	✓ 61.8	✓ 111	✓ 0.044	✓ 0.081

Initial overlying WQ measurements:	
Analyst NShergill	Date 2018 Sept 13

Final overlying WQ measurements:	
Analyst S. Rostama	Date 2018 Sep 27

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Saturday Day 14
Temp. (ºC)	23.1	23.8	23.9	23.6	23.4	23.7	23.8
D.O. (mg/L)	8.6	8.8	8.1	8.4	8.4	8.4	8.3
Subsampled for ammonia (√)	✓						✓
Analyst	NS	J	TW	mo	SR	mo	

Feeding–Day:	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Analyst	NS	~~J~~ N/A (A)	~~FW~~ J	N/A	N/A	TW	N/A	mo	N/A	SR	N/A	N/A	mo	N/A

Replicate	A	B	C	D	E
# Surviving	10	9	9	8	9
Analyst	SR	SR	SR	SR	SR

(E) clearification: probe in wrong solution for measurement -SR remeasured conductivity -SR 2018 Oct 22 LE

Date	Replicate	Comments and/or additional WQ measurements:	Analyst
2018 Sep 27	(B) ~~B~~C	There is lots of Daphnids ~~neonates~~ in the sample - especially in replicate C.	SR
		N/A MT 2018 Oct 03	

(A) WE J 2018 SEP19 (B) WE SR 2018 Sep 27 cond probe was not in the place -SR (E) (C) WE SR 2018 Sep 27 (d) values transcribed by MT 2018 Oct 16

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00143/6
Form: Sample

ECOTOXICOLOGY
HYALELLA AZTECA SURVIVAL AND GROWTH TEST - DATA SHEET

Sample ID: IC-1 1OF5
Job #/Sample #: B872132 UD7934
Start Date: September 13, 2018
End Date: September 27, 2018

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity (C) (mg/L $CaCO_3$)		Ammonia (C) (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.0	8.3	152	208	444	~~458~~ (B) 554	✓ 76.8	✓ 107	✓ 0.060	<0.020 ✓

Initial overlying WQ measurements:	
Analyst NShergill	Date 2018 Sept 13

Final overlying WQ measurements:	
Analyst S.Rostama	Date 2018 Sep 27

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Saturday Day 14
Temp. (ºC)	23.2	23.8	23.7	23.7	23.5	23.7	23.8
D.O. (mg/L)	8.6	8.5	8.1	8.4	8.5	8.4	8.3
Subsampled for ammonia (√)	✓						✓
Analyst	NS	J	TW	mo	SR	mo	

Feeding–Day:	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Analyst	NS	n/a ~~J~~ (A)	~~TW~~ (A)	n/a	n/a	TW	n/a	mo	n/a	SR	n/a	n/a	mo	n/a

Replicate	A	B	C	D	E
# Surviving	10	10	10	9	10
Analyst	SR	SR	SR	SR	SR

(D) clarification: probe in wrong solution for measurment and remeasured conductivity - SR 2018 oct 22 LE

Date	Replicate	Comments and/or additional WQ measurements:	Analyst
		N/A mt 2018 Oct 03	

(A) WE J 2018 SEP 19 (B) WE SR 2018 Sep 27 coud prob was not in the place - SR (D) (C) Values transcribed by mt 2018 Oct 16.

Maxxam
A Bureau Veritas Group Company

BBY2FCD-00143/6
Form: Sample

ECOTOXICOLOGY
HYALELLA AZTECA SURVIVAL AND GROWTH TEST - DATA SHEET

Sample ID: LZ-COMP 1OF5 **Start Date:** September 13, 2018

Job #/Sample #: B872132 UD7947 **End Date:** September 27, 2018

Measurements						Samples Taken			
pH		Hardness (mg/L $CaCO_3$)		Conductance (µS/cm)		Alkalinity Ⓒ (mg/L $CaCO_3$)		Ammonia Ⓒ (mg/L)	
Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
8.0	8.4	160	220	449	~~458~~ Ⓑ 577	✓ 76.1	✓ 118	✓ 0.10	<0.020 ✓

Initial overlying WQ measurements:	
Analyst NSmergill	Date 2018Sept13

Final overlying WQ measurements:	
Analyst S.Rostama	Date 2018Sep 27

Day	Thursday Day 0	Saturday Day 2	Tuesday Day 5	Thursday Day 7	Saturday Day 9	Tuesday Day 12	Saturday Day 14
Temp. (ºC)	23.2	23.7	23.7	23.7	23.6	23.7	23.9
D.O. (mg/L)	8.6	8.8	8.3	8.4	8.3	8.4	8.2
Subsampled for ammonia (√)	✓						✓
Analyst	NS	J	TW	mo	SR	mo	

Feeding–Day:	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Analyst	NS	Ⓐ ~~n/a~~ J	~~TW~~	N/A	N/A	TW	N/A	mo	N/A	SR	N/A	N/A	mo	N/A

Replicate	A	B	C	D	E
# Surviving	10	10	10	10	8
Analyst	SR	SR	SR	SR	SR

Ⓓ clarifications: probe in wrong solution for measurment - Remeasured conductivity - SR 2018 oct 22 L.E

Date	Replicate	Comments and/or additional WQ measurements:	Analyst
		N/A MH 2018 Oct 03	

Ⓐ WE J 2018 SEP19 Ⓑ WE SR 2018 sep 27. cond prob was not in the place Ⓓ
Ⓒ values transcribed by MH 2018Oct16

001287

ECOTOXICOLOGY
***HYALELLA AZTECA* SURVIVAL AND GROWTH TEST – AERATION CHECKS**

Client # & Name: 11052 - Hatfield   Start Date: 2018 Sept ~~12~~ 13
WE/LE NB 2018 Oct 22
WE NB 2018 Oct 22

Initial when aeration is checked. If air is off record DO and note which replicate(s) in comments section.

	Day -1	Day 0	1	2	3	4	5	6
Date	2018 Sept 12	2018 Sept 13	2018 Sept 14	2018 Sep 15	2018 Sept 16	2018 Sept 17	2018 Sept 18	2018 Sep 19
Early AM	n/a	NS	PH	SR	NS	NB	NB	mo
Mid-day	n/a	NS	NB	SR	NS.	NB	TW	mo
Late PM	NB	NS	mo	SR	NS	NB	TW	mo

	Day 7	8	9	10	11	12	13	14
Date	2018 Sep 20	2018 Sept 21	2018 Sep 22	2018 Sept 23	2018 Sep 24	2018 Sep 25	2018 Sep 26	2018 Sep 27
Early AM	mo	NB	SR	NB	TW	TW	TW	TW
Mid-day	mo	NB	SR	NB	mo	mo	SR	SR
Late PM	mo	NB	SR	NB	mo	mo	SR	n/a

Comments:

2018 Sept 12 - aeration started @ 17:26 - NB

2018 Sep 27 - test ended @ 2018 Sep 27 @ 14:00 SR

N/A MI 2018 Oct 16

SAM-5S Water Recipe for Hyalella

BATCH ID : 2018 Sep10
(Date Hardened)

SAM-5S Reconstituted Water Recipe for *Hyalella azteca* as per Borgmann 1996 (For water hardness ~125 mg/L)

Chemical Weights	$CaCl_2X2H_2O$	$MgSO_4$ (g)	NaBr (g)	$NaHCO_3$ (g)	KCl (g)
Brand	Fisher	Fisher	Acros	Fisher	Fisher
Lot #	171431	171667	20513000	177037	149363
Calculated	7.35	1.50	0.05	4.20	0.19
Actual	7.3505	1.4998	0.0500	4.2001	0.1895

Balance ID: BBY2-0260

Analyst: DML

Add to Type 3 DI (L): 50

Water Use: Hyalella

DI Machine ID: BBY2-0160

Date: 2018 Sep10

Water Quality:

Temp (°C): 21.5 pH: 8.2 Hardness (mg/L): 124

Cond (µs/cm): 424 DO (mg/L): 8.6 Alkalinity (mg/L): n/a

Analyst: D.Lai Date: 2018 Sep11

Comments: N/A

NaHCO3 (Sodium Bicarbonate)

NaBr (Sodium Bromide)

CaCl2 x 2H2O (Calcium Chloride - dihydrous)

MgSO4 (Magnesium Sulfate - anhydrous)

KCl (Potassium Chloride)

SAM-5S Recipe = 1 mM CaCl2, 1 mM NaHCO3, 0.01 mM NaBr, 0.05 mM KCl, and 0.25 mM MgSO4

Borgmann, U. 1996. Systematic analysis of aqueous ion requirements of *Hyalella azteca* : A standard artificial medium including the essential bromide ion. *Archives of Environmental Contamination and Toxicology*. 30: 356-363.

ECOTOXICOLOGY

ORGANISMS - ACCLIMATION AND HOLDING CONDITIONS

Client #'s : 11052

Date & Time of Arrival: 2018 Sep 11 @ 1200

Organism Lot #: AB180911

Age upon Arrival: 5-7 days

Water (L) per Shipping Bag: 1L

Organism: Hyalella

Number of Shipping Bags: 1

#of Organisms Ordered: 440

Light Intensity (lux): 603-678

Arrival Conditions

Bag ID	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	Analyst
A	0	0	1116	21.0	21.0	7.6	✓	DML

N/A MT 2018Oct03

Daily Conditions During Holding/Acclimation

Date	Mortalities		Water Quality					Analyst
	# Dead	% Dead	Cond (µS/cm)/ Salinity (ppt)	Temp (°C)	DO (mg/L)	pH	Feeding	
2018Sept12	0	0	1596	22.3	8.6	7.6	✓	DML
2018Sept13	0	0	752	22.3	8.6	8.0	✓	NS
Total Mortalities								

N/A MT 2018 Oct 03

Equipment ID: BBY2-0368

Comments (e.g. feeding times and quantities; fish behaviour, acclimation conditions): — **Analyst**

- 2018 Sept 11, rec'd organisms, poured into pyrex + aerated — DML
- 2018 Sept 12 did 50% H_2O Δ — DML
- 2018 Sept 13 - H_2O Δ ≈ 40% — NS

AB180911

1300 Blue Spruce Drive, Suite C
Fort Collins, Colorado 80524

AQUATIC BIO SYSTEMS ABS INC.

Toll Free: 800/331-5916
Tel: 970/484-5091 Fax:970/484-2514

ORGANISM HISTORY

DATE: 9/10/2018

SPECIES: *Hyalella azteca*

AGE: 4-6 day 5-7

LIFE STAGE: Juvenile

HATCH DATE: Variable

BEGAN FEEDING: Immediately

FOOD: Flake slurry

Water Chemistry Record:	Current	Range
TEMPERATURE:	25°C	23-26°C
SALINITY/CONDUCTIVITY:	--	--
TOTAL HARDNESS (as $CaCO_3$):	114 mg/l	96-200 mg/l
TOTAL ALKALINITY (as $CaCO_3$):	75 mg/l	50-80 mg/l
pH:	7.83	7.20-8.20

Comments:

Facility Supervisor

Aquatic BioSystems, Inc • Quality Research Organisms

Randomization Chart

Tab: Sediment Tests

Test: Hyalella

Start Date: 2018 Sep 13

Client # & Name: 11052 Hatfield

Back Wall		Position Map	
6	12	18	
5	11	17	
4	10	16	
3	9	15	
2	8	14	
1	7	13	etc.

Front of Counter

Position #	Sample ID	Replicate	Colour
22	Negative Control	A	Red
3		B	
6		C	
2		D	
20		E	
4		Measure	
13	PZ-1 OF 5	A	Orange
9		B	
12		C	
24		D	
18		E	
10		Measure	
15	IC-1 1OF5	A	Purple
23		B	
5		C	
1		D	
11		E	
21		Measure	
16	LZ-COMP 10F5	A	Dark Green
19		B	
7		C	
14		D	
8		E	
17		Measure	
25		A	Yellow
26		B	
27		C	
28		D	
29		E	
30		Measure	
31		A	Dark Blue
32		B	
33		C	
34		D	
35		E	
36		Measure	

Position #	Sample ID	Replicate	Colour
37		A	Pink
38		B	
39		C	
40		D	
41		E	
42		Measure	
43		A	White
44		B	
45		C	
46		D	
47		E	
48		Measure	
49		A	Light Blue
50		B	
51		C	
52		D	
53		E	
54		Measure	
55		A	Light Green
56		B	
57		C	
58		D	
59		E	
60		Measure	
61		A	Pink/Yellow
62		B	
63		C	
64		D	
65		E	
66		Measure	
67		A	Red/Green
68		B	
69		C	
70		D	
71		E	
72		Measure	

Maxxam
A Bureau Veritas Group Company

Success Through Science

Maxxam Job #: B879193
Report Date: 2018/09/19

Maxxam Analytics (TOX Internal)
Client Project #: Water only Hyalella chemistry
Sampler Initials: NS

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UH8843	UH8844	UH8845	UH8846	
Sampling Date		2017/09/13 16:00	2017/09/13 16:00	2017/09/13 16:00	2017/09/13 16:00	
COC Number		8714	8714	8714	8714	
	UNITS	Control Overly Day 0 Hy	LZ-COMP Overly DAy 0 HY	IC-1 Overly Day 0 Hy	PZ-1 OVerly Day 0 HY	RDL
Misc. Inorganics						
Alkalinity (Total as CaCO3)	mg/L	56.9	76.1	76.8	61.8	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	69.4	92.8	93.7	75.4	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	1.0
Nutrients						
Total Ammonia (N)	mg/L	<0.020	0.10	0.060	0.044	0.020
RDL = Reportable Detection Limit						

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Maxxam Job #: B884148
Report Date: 2018/10/03

Maxxam Analytics (TOX Internal)
Sampler Initials: SR

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UK7567	UK7568	UK7570	
Sampling Date		2018/09/27	2018/09/27	2018/09/27	
COC Number		9058	9058	9058	
	UNITS	control overly water day 14 hyalella	PZ-1 overly water day 14 hyalella	LZ overly water day 14 hyalella	RDL
Misc. Inorganics					
Alkalinity (Total as CaCO3)	mg/L	77.5	111	118	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	<1.0	<1.0	1.0
Bicarbonate (HCO3)	mg/L	94.5	135	144	1.0
Carbonate (CO3)	mg/L	<1.0	<1.0	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	1.0
Nutrients					
Total Ammonia (N)	mg/L	0.48	0.081	<0.020	0.020
RDL = Reportable Detection Limit					

Maxxam Job #: B884148
Report Date: 2018/10/03

Maxxam Analytics (TOX Internal)
Sampler Initials: SR

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		UK7569	
Sampling Date		2018/09/27	
COC Number		9058	
	UNITS	IC-1 overly water day 14 hyalella	RDL
Misc. Inorganics			
Alkalinity (Total as CaCO3)	mg/L	107	1.0
Alkalinity (PP as CaCO3)	mg/L	<1.0	1.0
Bicarbonate (HCO3)	mg/L	130	1.0
Carbonate (CO3)	mg/L	<1.0	1.0
Hydroxide (OH)	mg/L	<1.0	1.0
Nutrients			
Total Ammonia (N)	mg/L	<0.020	0.020
RDL = Reportable Detection Limit			

Maxxam Analytics International Corporation o/a Maxxam Analytics Burnaby: 4606 Canada Way V5G 1K5 Telephone(604) 734-7276 Fax(604) 731-2386

Hatfield Consultants
ATTN: Chris Jaeggle/Andrew O'Gorman
200 - 850 Harbourside Drive
North Vancouver BC V7P 0A3

Date Received: 24-AUG-18
Report Date: 10-SEP-18 16:29 (MT)
Version: FINAL

Client Phone: 604-926-3621

Certificate of Analysis

Lab Work Order #: L2152759
Project P.O. #: NOT SUBMITTED
Job Reference: CNUL9184
C of C Numbers:
Legal Site Desc:

Dana Brown, Chem. Tech. DIPL
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-1 PZ-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
CCME BTEX, F1 TO F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Toluene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Ethylbenzene	<0.010		0.010	mg/kg	23-AUG-18	28-AUG-18	R4175505
m+p-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
o-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Xylenes	<0.10		0.10	mg/kg	23-AUG-18	28-AUG-18	R4175505
Surrogate: 1,4-Difluorobenzene (SS)	82.0		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 4-Bromofluorobenzene (SS)	73.6		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 3,4-Dichlorotoluene (SS)	77.0		70-130	%	23-AUG-18	28-AUG-18	R4175505
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	78.9		70-130	%	25-AUG-18	25-AUG-18	R4183383
Chrom. to baseline at nC50	YES				25-AUG-18	25-AUG-18	R4183383
Prep/Analysis Dates					25-AUG-18	25-AUG-18	R4183383
CCME Total Hydrocarbons							
F1 (C6-C10)	<10		10	mg/kg		30-AUG-18	
F1-BTEX	<10		10	mg/kg		30-AUG-18	
F2 (C10-C16)	<20		20	mg/kg		30-AUG-18	
F2-Naphth	<20		20	mg/kg		30-AUG-18	
F3 (C16-C34)	23		20	mg/kg		30-AUG-18	
F3-PAH	23		20	mg/kg		30-AUG-18	
F4 (C34-C50)	34		20	mg/kg		30-AUG-18	
F4G-SG (GHH-Silica)	<500		500	mg/kg		30-AUG-18	
Total Hydrocarbons (C6-C50)	57		20	mg/kg		30-AUG-18	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	2.95		0.40	%		04-SEP-18	
Total Carbon by combustion method							
Total Carbon by Combustion	1.06		0.05	%	01-SEP-18	01-SEP-18	R4196285
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.355		0.050	%		04-SEP-18	R4198789
Total Organic Carbon Calculation							
Total Organic Carbon	0.71		0.21	%		04-SEP-18	
Miscellaneous Parameters							
% Moisture	31.3		0.50	%		25-AUG-18	R4183066
F4G Prep/Analysis Dates					25-AUG-18	27-AUG-18	R4183957
Mercury (Hg)	0.0100		0.0050	mg/kg	01-SEP-18	01-SEP-18	R4196180
Particle Size							
% Sand	59.8		1.0	%		29-AUG-18	R4192391
% Silt	20.2		1.0	%		29-AUG-18	R4192391
% Clay	20.0		1.0	%		29-AUG-18	R4192391
Texture	Sandy loam / Sandy clay loam					29-AUG-18	R4192391
Particle size - Pipette removal OM & CO3							
% Sand (2.0mm - 0.05mm)	68.6		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Silt (0.05mm - 2um)	23.1		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Clay (<2um)	8.3		1.0	%	06-SEP-18	07-SEP-18	R4205338
Texture	Sandy loam				06-SEP-18	07-SEP-18	R4205338
Metals in Soil by CRC ICPMS							
Aluminum (Al)	5460		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Antimony (Sb)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Arsenic (As)	1.77		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-1 PZ-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
Metals in Soil by CRC ICPMS							
Barium (Ba)	38.7		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Beryllium (Be)	0.27		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Bismuth (Bi)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Boron (B)	5.9		5.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cadmium (Cd)	0.020		0.020	mg/kg	01-SEP-18	03-SEP-18	R4196800
Calcium (Ca)	8870		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Chromium (Cr)	10.4		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cobalt (Co)	2.92		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Copper (Cu)	4.41		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Iron (Fe)	7900		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lead (Pb)	4.02		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lithium (Li)	6.4		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Magnesium (Mg)	2490		20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Manganese (Mn)	102		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Molybdenum (Mo)	0.30		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Nickel (Ni)	7.85		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Phosphorus (P)	137		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Potassium (K)	740		100	mg/kg	01-SEP-18	03-SEP-18	R4196800
Selenium (Se)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Silver (Ag)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sodium (Na)	69		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Strontium (Sr)	24.9		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sulfur (S)	<1000		1000	mg/kg	01-SEP-18	03-SEP-18	R4196800
Thallium (Tl)	0.052		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tin (Sn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Titanium (Ti)	74.6		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tungsten (W)	<0.50		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Uranium (U)	0.319		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Vanadium (V)	14.7		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zinc (Zn)	11.5		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zirconium (Zr)	9.6		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
PAH & Alkylated PAH List							
Acenaphthene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acenaphthylene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acridine	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Anthracene	<0.0040		0.0040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benz(a)anthracene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(a)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(e)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(b&j)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(k)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(g,h,i)perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Biphenyl	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 sub'd B(a)A/chrysene	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-1 PZ-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
PAH & Alkylated PAH List							
C3 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Chrysene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenz(a,h)anthracene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenzothiophene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluorene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Indeno(1,2,3-cd)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benz(a)Anthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Acenaphthenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
1-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
2-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Naphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Phenanthrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Quinoline	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Retene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Acenaphthene	83.5		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d12-Chrysene	89.1		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d8-Naphthalene	77.4		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Phenanthrene	82.0		50-140	%	28-AUG-18	30-AUG-18	R4194849
L2152759-2 IC-1							
Sampled By: AO/AJ on 23-AUG-18 @ 15:10							
Matrix: Sediment							
CCME BTEX, F1 TO F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Toluene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Ethylbenzene	<0.010		0.010	mg/kg	23-AUG-18	28-AUG-18	R4175505
m+p-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
o-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Xylenes	<0.10		0.10	mg/kg	23-AUG-18	28-AUG-18	R4175505
Surrogate: 1,4-Difluorobenzene (SS)	84.5		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 4-Bromofluorobenzene (SS)	79.8		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 3,4-Dichlorotoluene (SS)	90.1		70-130	%	23-AUG-18	28-AUG-18	R4175505

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-2 IC-1							
Sampled By: AO/AJ on 23-AUG-18 @ 15:10							
Matrix: Sediment							
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	83.2		70-130	%	25-AUG-18	25-AUG-18	R4183383
Chrom. to baseline at nC50	YES				25-AUG-18	25-AUG-18	R4183383
Prep/Analysis Dates					25-AUG-18	25-AUG-18	R4183383
CCME Total Hydrocarbons							
F1 (C6-C10)	<10		10	mg/kg		30-AUG-18	
F1-BTEX	<10		10	mg/kg		30-AUG-18	
F2 (C10-C16)	<20		20	mg/kg		30-AUG-18	
F2-Naphth	<20		20	mg/kg		30-AUG-18	
F3 (C16-C34)	47		20	mg/kg		30-AUG-18	
F3-PAH	47		20	mg/kg		30-AUG-18	
F4 (C34-C50)	39		20	mg/kg		30-AUG-18	
F4G-SG (GHH-Silica)	<500		500	mg/kg		30-AUG-18	
Total Hydrocarbons (C6-C50)	86		20	mg/kg		30-AUG-18	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	0.53		0.40	%		04-SEP-18	
Total Carbon by combustion method							
Total Carbon by Combustion	0.32		0.05	%	01-SEP-18	01-SEP-18	R4196285
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.063		0.050	%		04-SEP-18	R4198789
Total Organic Carbon Calculation							
Total Organic Carbon	0.258		0.050	%		04-SEP-18	
Miscellaneous Parameters							
% Moisture	23.0		0.50	%		25-AUG-18	R4183066
F4G Prep/Analysis Dates					25-AUG-18	27-AUG-18	R4183957
Mercury (Hg)	<0.0050		0.0050	mg/kg	01-SEP-18	01-SEP-18	R4196180
Particle Size							
% Sand	95.8		1.0	%		29-AUG-18	R4192391
% Silt	4.2		1.0	%		29-AUG-18	R4192391
% Clay	<1.0		1.0	%		29-AUG-18	R4192391
Texture	Sand					29-AUG-18	R4192391
Particle size - Pipette removal OM & CO3							
% Sand (2.0mm - 0.05mm)	97.8		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Silt (0.05mm - 2um)	1.4		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Clay (<2um)	<1.0		1.0	%	06-SEP-18	07-SEP-18	R4205338
Texture	Sand				06-SEP-18	07-SEP-18	R4205338
Metals in Soil by CRC ICPMS							
Aluminum (Al)	450		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Antimony (Sb)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Arsenic (As)	0.35		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Barium (Ba)	5.86		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Beryllium (Be)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Bismuth (Bi)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Boron (B)	<5.0		5.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cadmium (Cd)	<0.020		0.020	mg/kg	01-SEP-18	03-SEP-18	R4196800
Calcium (Ca)	2020		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Chromium (Cr)	1.17		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cobalt (Co)	0.41		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Copper (Cu)	0.90		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Iron (Fe)	1210		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lead (Pb)	0.73		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-2 IC-1							
Sampled By: AO/AJ on 23-AUG-18 @ 15:10							
Matrix: Sediment							
Metals in Soil by CRC ICPMS							
Lithium (Li)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Magnesium (Mg)	680		20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Manganese (Mn)	26.0		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Molybdenum (Mo)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Nickel (Ni)	2.64		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Phosphorus (P)	<50		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Potassium (K)	<100		100	mg/kg	01-SEP-18	03-SEP-18	R4196800
Selenium (Se)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Silver (Ag)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sodium (Na)	<50		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Strontium (Sr)	6.53		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sulfur (S)	<1000		1000	mg/kg	01-SEP-18	03-SEP-18	R4196800
Thallium (Tl)	<0.050		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tin (Sn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Titanium (Ti)	18.1		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tungsten (W)	<0.50		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Uranium (U)	0.074		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Vanadium (V)	1.67		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zinc (Zn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zirconium (Zr)	1.2		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
PAH & Alkylated PAH List							
Acenaphthene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acenaphthylene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acridine	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Anthracene	<0.0040		0.0040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benz(a)anthracene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(a)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(e)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(b&j)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(k)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(g,h,i)perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Biphenyl	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 sub'd B(a)A/chrysene	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Chrysene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenz(a,h)anthracene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenzothiophene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-2 IC-1							
Sampled By: AO/AJ on 23-AUG-18 @ 15:10							
Matrix: Sediment							
PAH & Alkylated PAH List							
Fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluorene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Indeno(1,2,3-cd)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benz(a)Anthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Acenaphthenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
1-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
2-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Naphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Phenanthrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Quinoline	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Retene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Acenaphthene	86.4		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d12-Chrysene	93.5		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d8-Naphthalene	85.7		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Phenanthrene	95.3		50-140	%	28-AUG-18	30-AUG-18	R4194849
L2152759-3 LZ-COMP							
Sampled By: AO/AJ on 23-AUG-18 @ 13:10							
Matrix: Sediment							
CCME BTEX, F1 TO F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Toluene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Ethylbenzene	<0.010		0.010	mg/kg	23-AUG-18	28-AUG-18	R4175505
m+p-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
o-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Xylenes	<0.10		0.10	mg/kg	23-AUG-18	28-AUG-18	R4175505
Surrogate: 1,4-Difluorobenzene (SS)	86.2		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 4-Bromofluorobenzene (SS)	78.4		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 3,4-Dichlorotoluene (SS)	83.4		70-130	%	23-AUG-18	28-AUG-18	R4175505
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	77.1		70-130	%	25-AUG-18	25-AUG-18	R4183383
Chrom. to baseline at nC50	YES				25-AUG-18	25-AUG-18	R4183383
Prep/Analysis Dates					25-AUG-18	25-AUG-18	R4183383
CCME Total Hydrocarbons							
F1 (C6-C10)	<10		10	mg/kg		30-AUG-18	
F1-BTEX	<10		10	mg/kg		30-AUG-18	
F2 (C10-C16)	<20		20	mg/kg		30-AUG-18	
F2-Naphth	<20		20	mg/kg		30-AUG-18	
F3 (C16-C34)	73		20	mg/kg		30-AUG-18	
F3-PAH	73		20	mg/kg		30-AUG-18	

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-3 LZ-COMP							
Sampled By: AO/AJ on 23-AUG-18 @ 13:10							
Matrix: Sediment							
CCME Total Hydrocarbons							
F4 (C34-C50)	66		20	mg/kg		30-AUG-18	
F4G-SG (GHH-Silica)	<500		500	mg/kg		30-AUG-18	
Total Hydrocarbons (C6-C50)	139		20	mg/kg		30-AUG-18	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	1.02		0.40	%		04-SEP-18	
Total Carbon by combustion method							
Total Carbon by Combustion	0.35		0.05	%	01-SEP-18	01-SEP-18	R4196285
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.122		0.050	%		04-SEP-18	R4198789
Total Organic Carbon Calculation							
Total Organic Carbon	0.223		0.069	%		04-SEP-18	
Miscellaneous Parameters							
% Moisture	20.7		0.50	%		25-AUG-18	R4183066
F4G Prep/Analysis Dates					25-AUG-18	27-AUG-18	R4183957
Mercury (Hg)	<0.0050		0.0050	mg/kg	01-SEP-18	01-SEP-18	R4196180
Particle Size							
% Sand	94.2		1.0	%		29-AUG-18	R4192391
% Silt	5.8		1.0	%		29-AUG-18	R4192391
% Clay	<1.0		1.0	%		29-AUG-18	R4192391
Texture	Sand					29-AUG-18	R4192391
Particle size - Pipette removal OM & CO3							
% Sand (2.0mm - 0.05mm)	96.9		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Silt (0.05mm - 2um)	2.6		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Clay (<2um)	<1.0		1.0	%	06-SEP-18	07-SEP-18	R4205338
Texture	Sand				06-SEP-18	07-SEP-18	R4205338
Metals in Soil by CRC ICPMS							
Aluminum (Al)	394		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Antimony (Sb)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Arsenic (As)	0.36		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Barium (Ba)	5.63		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Beryllium (Be)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Bismuth (Bi)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Boron (B)	<5.0		5.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cadmium (Cd)	<0.020		0.020	mg/kg	01-SEP-18	03-SEP-18	R4196800
Calcium (Ca)	3070		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Chromium (Cr)	1.07		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cobalt (Co)	0.42		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Copper (Cu)	0.58		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Iron (Fe)	1060		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lead (Pb)	0.72		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lithium (Li)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Magnesium (Mg)	960		20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Manganese (Mn)	36.6		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Molybdenum (Mo)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Nickel (Ni)	1.01		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Phosphorus (P)	<50		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Potassium (K)	<100		100	mg/kg	01-SEP-18	03-SEP-18	R4196800
Selenium (Se)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Silver (Ag)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sodium (Na)	<50		50	mg/kg	01-SEP-18	03-SEP-18	R4196800

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-3 LZ-COMP							
Sampled By: AO/AJ on 23-AUG-18 @ 13:10							
Matrix: Sediment							
Metals in Soil by CRC ICPMS							
Strontium (Sr)	8.82		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sulfur (S)	<1000		1000	mg/kg	01-SEP-18	03-SEP-18	R4196800
Thallium (Tl)	<0.050		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tin (Sn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Titanium (Ti)	15.6		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tungsten (W)	<0.50		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Uranium (U)	0.070		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Vanadium (V)	1.47		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zinc (Zn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zirconium (Zr)	1.1		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
PAH & Alkylated PAH List							
Acenaphthene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acenaphthylene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acridine	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Anthracene	<0.0040		0.0040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benz(a)anthracene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(a)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(e)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(b&j)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(k)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(g,h,i)perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Biphenyl	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 sub'd B(a)A/chrysene	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Chrysene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenz(a,h)anthracene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenzothiophene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluorene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Indeno(1,2,3-cd)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benz(a)Anthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Acenaphthenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-3 LZ-COMP							
Sampled By: AO/AJ on 23-AUG-18 @ 13:10							
Matrix: Sediment							
PAH & Alkylated PAH List							
1-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
2-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Naphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Phenanthrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Quinoline	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Retene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Acenaphthene	89.4		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d12-Chrysene	94.8		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d8-Naphthalene	90.2		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Phenanthrene	92.3		50-140	%	28-AUG-18	30-AUG-18	R4194849
L2152759-4 SP-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
CCME BTEX, F1 TO F4							
BTEX and F1							
Benzene	<0.0050		0.0050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Toluene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Ethylbenzene	<0.010		0.010	mg/kg	23-AUG-18	28-AUG-18	R4175505
m+p-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
o-Xylene	<0.050		0.050	mg/kg	23-AUG-18	28-AUG-18	R4175505
Xylenes	<0.10		0.10	mg/kg	23-AUG-18	28-AUG-18	R4175505
Surrogate: 1,4-Difluorobenzene (SS)	91.0		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 4-Bromofluorobenzene (SS)	94.5		70-130	%	23-AUG-18	28-AUG-18	R4175505
Surrogate: 3,4-Dichlorotoluene (SS)	88.4		70-130	%	23-AUG-18	28-AUG-18	R4175505
CCME Total Extractable Hydrocarbons							
Surrogate: 2-Bromobenzotrifluoride	77.1		70-130	%	25-AUG-18	25-AUG-18	R4183383
Chrom. to baseline at nC50	YES				25-AUG-18	25-AUG-18	R4183383
Prep/Analysis Dates					25-AUG-18	25-AUG-18	R4183383
CCME Total Hydrocarbons							
F1 (C6-C10)	<10		10	mg/kg		30-AUG-18	
F1-BTEX	<10		10	mg/kg		30-AUG-18	
F2 (C10-C16)	<20		20	mg/kg		30-AUG-18	
F2-Naphth	<20		20	mg/kg		30-AUG-18	
F3 (C16-C34)	30		20	mg/kg		30-AUG-18	
F3-PAH	30		20	mg/kg		30-AUG-18	
F4 (C34-C50)	44		20	mg/kg		30-AUG-18	
F4G-SG (GHH-Silica)	<500		500	mg/kg		30-AUG-18	
Total Hydrocarbons (C6-C50)	74		20	mg/kg		30-AUG-18	
Total Carbon, TOC and TIC in soil							
Inorganic Carbon as CaCO3 Equivalent							
Inorganic Carbon (as CaCO3 Equivalent)	2.66		0.40	%		04-SEP-18	
Total Carbon by combustion method							
Total Carbon by Combustion	1.00		0.05	%	01-SEP-18	01-SEP-18	R4196285
Total Inorganic Carbon in Soil							
Inorganic Carbon	0.319		0.050	%		04-SEP-18	R4198789

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-4 SP-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
Total Organic Carbon Calculation							
Total Organic Carbon	0.681		0.050	%		04-SEP-18	
Miscellaneous Parameters							
% Moisture	25.3		0.50	%		25-AUG-18	R4183066
F4G Prep/Analysis Dates					25-AUG-18	27-AUG-18	R4183957
Mercury (Hg)	0.0091		0.0050	mg/kg	01-SEP-18	01-SEP-18	R4196180
Particle Size							
% Sand	61.8		1.0	%		29-AUG-18	R4192391
% Silt	18.2		1.0	%		29-AUG-18	R4192391
% Clay	20.0		1.0	%		29-AUG-18	R4192391
Texture	Sandy loam / Sandy clay loam					29-AUG-18	R4192391
Particle size - Pipette removal OM & CO3							
% Sand (2.0mm - 0.05mm)	69.9		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Silt (0.05mm - 2um)	25.1		1.0	%	06-SEP-18	07-SEP-18	R4205338
% Clay (<2um)	5.0		1.0	%	06-SEP-18	07-SEP-18	R4205338
Texture	Sandy loam				06-SEP-18	07-SEP-18	R4205338
Metals in Soil by CRC ICPMS							
Aluminum (Al)	5390		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Antimony (Sb)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Arsenic (As)	1.81		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Barium (Ba)	36.4		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Beryllium (Be)	0.27		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Bismuth (Bi)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Boron (B)	6.4		5.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cadmium (Cd)	0.024		0.020	mg/kg	01-SEP-18	03-SEP-18	R4196800
Calcium (Ca)	8680		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Chromium (Cr)	9.89		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Cobalt (Co)	2.78		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Copper (Cu)	4.15		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Iron (Fe)	7310		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lead (Pb)	4.15		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Lithium (Li)	6.4		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Magnesium (Mg)	2640		20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Manganese (Mn)	97.2		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Molybdenum (Mo)	0.30		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Nickel (Ni)	7.29		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Phosphorus (P)	144		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Potassium (K)	780		100	mg/kg	01-SEP-18	03-SEP-18	R4196800
Selenium (Se)	<0.20		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Silver (Ag)	<0.10		0.10	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sodium (Na)	70		50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Strontium (Sr)	24.5		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Sulfur (S)	<1000		1000	mg/kg	01-SEP-18	03-SEP-18	R4196800
Thallium (Tl)	<0.050		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tin (Sn)	<2.0		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Titanium (Ti)	92.1		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Tungsten (W)	<0.50		0.50	mg/kg	01-SEP-18	03-SEP-18	R4196800
Uranium (U)	0.322		0.050	mg/kg	01-SEP-18	03-SEP-18	R4196800
Vanadium (V)	14.4		0.20	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zinc (Zn)	11.4		2.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
Zirconium (Zr)	9.7		1.0	mg/kg	01-SEP-18	03-SEP-18	R4196800
PAH & Alkylated PAH List							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-4 SP-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
PAH & Alkylated PAH List							
Acenaphthene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acenaphthylene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Acridine	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Anthracene	<0.0040		0.0040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benz(a)anthracene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(a)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(e)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(b&j)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(k)fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Benzo(g,h,i)perylene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Biphenyl	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 sub'd B(a)A/chrysene	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Naphthalenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Benzanthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Chrysene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenz(a,h)anthracene	<0.0050		0.0050	mg/kg	28-AUG-18	30-AUG-18	R4194849
Dibenzothiophene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluoranthene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Fluorene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Indeno(1,2,3-cd)pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benz(a)Anthracenes/Chrysenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Benzofluoranthenes/Benzopyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Acenaphthenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Biphenyls	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Dibenzothiophenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
1-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
2-Methylnaphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C1 Phenanthrenes/Anthracenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
Naphthalene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Phenanthrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Pyrene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Quinoline	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
C2 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C3 Fluorenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849
C4 Fluoranthenes/Pyrenes	<0.040		0.040	mg/kg	28-AUG-18	30-AUG-18	R4194849

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L2152759-4 SP-1							
Sampled By: AO/AJ on 23-AUG-18 @ 09:17							
Matrix: Sediment							
PAH & Alkylated PAH List							
Retene	<0.010		0.010	mg/kg	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Acenaphthene	93.3		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d12-Chrysene	99.3		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d8-Naphthalene	91.4		50-140	%	28-AUG-18	30-AUG-18	R4194849
Surrogate: d10-Phenanthrene	92.1		50-140	%	28-AUG-18	30-AUG-18	R4194849

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.
DUP-H,J	Duplicate results outside ALS DQO, due to sample heterogeneity. Duplicate results and limits are expressed in terms of absolute difference.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
BTXS,F1-MEOH-ED	Soil	BTEX and F1	EPA 8260C/5021A and CWS PHC Tier 1

This analysis involves the extraction of a subsample of the sediment/soil with methanol added in the field at the time of subsampling. The soil methanol extract is added to water and reagents, then heated in a sealed vial to equilibrium. The headspace from the vial is transferred into a gas chromatograph. BTX Target compound concentrations are measured using mass spectrometry detection. The instrumental portion of F1 analysis is carried out in accordance with the Canada Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method (2001).

C-TIC-PCT-SK	Soil	Total Inorganic Carbon in Soil	CSSS (2008) P216-217

A known quantity of acetic acid is consumed by reaction with carbonates in the soil. The pH of the resulting solution is measured and compared against a standard curve relating pH to weight of carbonate.

C-TOC-CALC-SK	Soil	Total Organic Carbon Calculation	CSSS (2008) 21.2

Total Organic Carbon (TOC) is calculated by the difference between total carbon (TC) and total inorganic carbon. (TIC)

C-TOT-LECO-SK	Soil	Total Carbon by combustion method	CSSS (2008) 21.2

The sample is ignited in a combustion analyzer where carbon in the reduced CO_2 gas is determined using a thermal conductivity detector.

ETL-TVH,TEH-CCME-ED	Soil	CCME Total Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

Analytical methods used for analysis of CCME Petroleum Hydrocarbons have been validated and comply with the Reference Method for the CWS PHC.

Hydrocarbon results are expressed on a dry weight basis.

In cases where results for both F4 and F4G are reported, the greater of the two results must be used in any application of the CWS PHC guidelines and the gravimetric heavy hydrocarbons cannot be added to the C6 to C50 hydrocarbons.
In samples where BTEX and F1 were analyzed , F1-BTEX represents a value where the sum of Benzene, Toluene, Ethylbenzene and total Xylenes has been subtracted from F1.

In samples where PAHs, F2 and F3 were analyzed, F2-Naphth represents the result where Naphthalene has been subtracted from F2. F3-PAH represents a result where the sum of Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenzo(a,h)anthracene, Fluoranthene, Indeno(1,2,3-cd)pyrene, Phenanthrene, and Pyrene has been subtracted from F3.

Unless otherwise qualified, the following quality control criteria have been met for the F1 hydrocarbon range:
1. All extraction and analysis holding times were met.
2. Instrument performance showing response factors for C6 and C10 within 30% of the response factor for toluene.
3. Linearity of gasoline response within 15% throughout the calibration range.

Unless otherwise qualified, the following quality control criteria have been met for the F2-F4 hydrocarbon ranges:
1. All extraction and analysis holding times were met.
2. Instrument performance showing C10, C16 and C34 response factors within 10% of their average.
3. Instrument performance showing the C50 response factor within 30% of the average of the C10, C16 and C34 response factors.
4. Linearity of diesel or motor oil response within 15% throughout the calibration range.

F2-4-TMB-ED	Soil	CCME Total Extractable Hydrocarbons	CCME CWS-PHC, Pub #1310, Dec 2001

This analysis is carried out in accordance with the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment" For C10 to C50 hydrocarbons (F2, F3, F4) and gravimetric heavy hydrocarbons (F4G-sg), a subsample of the sediment/soil is extracted with 1:1 hexane:acetone using a rotary extractor. The extract undergoes a silica-gel clean-up to remove polar compounds. F2, F3 & F4 are analyzed by on-column GC/FID, and F4G-sg is analyzed gravimetrically.

Notes:
1. F2 (C10-C16): Sum of all hydrocarbons that elute between nC10 and nC16.
2. F3 (C16-C34): Sum of all hydrocarbons that elute between nC16 and nC34.
3. F4 (C34-C50): Sum of all hydrocarbons that elute between nC34 and nC50.
4. F4G: Gravimetric Heavy Hydrocarbons
5. F4G-sg: Gravimetric Heavy Hydrocarbons (F4G) after silica gel treatment.
6. Where F4 (C34-C50) and F4G-sg results are reported for a sample, the larger of the reported values is used for comparison against the relevant CCME standard for F4.
7. The gravimetric heavy hydrocarbon results (F4G-sg), cannot be added to the C6 to C50 hydrocarbon results.
8. This method is validated for use.
9. Data from analysis of quality control samples is available upon request.
10. Reported results are expressed as milligrams per dry kilogram.

F4G-TMB-ED	Soil	CCME Gravimetric Heavy Hydrocarbons (SG)	CCME CWS-PHC, Pub #1310, Dec 2001

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
HG-200.2-CVAA-ED	Soil	Mercury in Soil by CVAAS	EPA 200.2/1631E (Mod)

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CVAAS.

ALS Test Code	Matrix	Test Description	Method Reference**
IC-CACO3-CALC-SK	Soil	Inorganic Carbon as CaCO3 Equivalent	Calculation
MET-200.2-CCMS-ED	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A (mod)

This method uses a heated strong acid digestion with HNO3 and HCl and is intended to liberate metals that may be environmentally available. Silicate minerals are not solubilized. Dependent on sample matrix, some metals may be only partially recovered, including Al, Ba, Be, Cr, Sr, Ti, Tl, V, W, and Zr. Volatile forms of sulfur (including sulfide) may not be captured, as they may be lost during sampling, storage, or digestion. Analysis is by Collision/Reaction Cell ICPMS.

ALS Test Code	Matrix	Test Description	Method Reference**
PAH-ALK-GCMS-CL	Soil	PAH & Alkylated PAH List	EPA 3570/8270-GC/MS

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3570 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of dichlomethane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

NOTE: The following PAH parameter results are determined by a semi-quantitative method.

C1 B(a)A/chrysene
C1B(b&kF/B(a)P
C1 acenaphthene
C1 biphenyl
C1dibenzothiophene
C1 fluoranthene/pyrene
C1 fluorene
C1 naphthalene
C1 phenanthrene/anthracene
C2 B(a)A/chrysene
C2 b(b&k)F/b(a)P
C2 biphenyl
C2 dibenzothiophene
C2 fluoranthene/pyrene
C2 fluorene
C2 naphtalene
C2 phenanthrene/anth.
C3 dibenzothiophene
C3 fluorene
C3 naphthalene
C3 phenanthrene/anth.
C4 dibenzothiophene
C4 naphthalene
C4 phenanthrene/anth.

ALS Test Code	Matrix	Test Description	Method Reference**
PREP-MOISTURE-ED	Soil	% Moisture	Oven dry 105C-Gravimetric

The weighed portion of soil is placed in a 105 C oven to dry to a constant weight; the drying time will vary based on the moisture content of the soil. The dried soil weight is then used to calculate % moisture.

Reference: ASTM D2974-00.

ALS Test Code	Matrix	Test Description	Method Reference**
PSA-1-ED	Soil	Particle Size	CSSS 55.3-Hydrometer

Soil samples are oven dried, ground to pass a 2 mm sieve , and soaked in Calgon solution for a minimum of 16 hours. Soil suspensions are measured for particle size by distribution using a hydrometer after specified settling times.

ALS Test Code	Matrix	Test Description	Method Reference**
PSA-3-SK	Soil	Particle size - Pipette removal OM & CO3	Forestry Canada (1991) p. 46-53

Dry, < 2 mm soil is treated hydrochloric acid top remove carbonates, then hydrogen peroxide to remove organic matter. The remaining soil is treated with sodium hexametaphosphate to ensure complete dispersion of primary soil particles. The homogenized suspension is allowed to settle in accordance with Stoke's Law so that only clay particles remain in suspension.To determine the clay fraction, an aliquot of the clay suspension is removed, then dried and weighed. The sand fraction is determined by wet sieving the remaining suspension, then drying and weighing the sand retained on the sieve. The silt fraction is determined by calculation where % Silt = 100 - (%Sand+%Clay)

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

ALS Environmental

Quality Control Report

Workorder: L2152759 Report Date: 10-SEP-18

Client: Hatfield Consultants
200 - 850 Harbourside Drive
North Vancouver BC V7P 0A3
Contact: Chris Jaeggle/Andrew O'Gorman

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BTXS,F1-MEOH-ED	Soil							
Batch R4175505								
WG2859725-4 DUP		**L2152759-1**						
Benzene		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	30	28-AUG-18
Toluene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	28-AUG-18
Ethylbenzene		<0.010	<0.010	RPD-NA	mg/kg	N/A	30	28-AUG-18
m+p-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	28-AUG-18
o-Xylene		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	28-AUG-18
WG2859725-2 LCS								
Benzene			81.0		%		70-130	28-AUG-18
Toluene			80.9		%		70-130	28-AUG-18
Ethylbenzene			91.2		%		70-130	28-AUG-18
m+p-Xylene			88.0		%		70-130	28-AUG-18
o-Xylene			90.0		%		70-130	28-AUG-18
WG2859725-1 MB								
Benzene			<0.0050		mg/kg		0.005	28-AUG-18
Toluene			<0.050		mg/kg		0.05	28-AUG-18
Ethylbenzene			<0.010		mg/kg		0.01	28-AUG-18
m+p-Xylene			<0.050		mg/kg		0.05	28-AUG-18
o-Xylene			<0.050		mg/kg		0.05	28-AUG-18
Surrogate: 1,4-Difluorobenzene (SS)			97.6		%		70-130	28-AUG-18
Surrogate: 4-Bromofluorobenzene (SS)			92.7		%		70-130	28-AUG-18
Surrogate: 3,4-Dichlorotoluene (SS)			101.3		%		70-130	28-AUG-18
WG2859725-5 MS		**L2152759-4**						
Benzene			115.7		%		50-140	28-AUG-18
Toluene			114.7		%		50-140	28-AUG-18
Ethylbenzene			125.2		%		50-140	28-AUG-18
m+p-Xylene			119.1		%		50-140	28-AUG-18
o-Xylene			122.6		%		50-140	28-AUG-18
C-TIC-PCT-SK	Soil							
Batch R4198789								
WG2862850-2 LCS								
Inorganic Carbon			100.5		%		80-120	04-SEP-18
WG2862850-3 MB								
Inorganic Carbon			<0.050		%		0.05	04-SEP-18
C-TOT-LECO-SK	Soil							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TOT-LECO-SK	Soil							
Batch R4196285								
WG2863537-2 IRM		**08-109_SOIL**						
Total Carbon by Combustion			94.9		%		80-120	01-SEP-18
WG2863537-5 LCS		**SULFADIAZINE**						
Total Carbon by Combustion			97.8		%		90-110	01-SEP-18
WG2863537-4 MB								
Total Carbon by Combustion			<0.05		%		0.05	01-SEP-18
F2-4-TMB-ED	Soil							
Batch R4183383								
WG2859820-3 IRM		**ALS PHC2 RM**						
F2 (C10-C16)			85.2		%		70-130	25-AUG-18
F3 (C16-C34)			95.4		%		70-130	25-AUG-18
F4 (C34-C50)			97.0		%		70-130	25-AUG-18
WG2859820-2 LCS		**DIESEL/MOTOR OIL**						
F2 (C10-C16)			104.0		%		70-130	25-AUG-18
F3 (C16-C34)			113.4		%		70-130	25-AUG-18
F4 (C34-C50)			110.8		%		70-130	25-AUG-18
WG2859820-1 MB								
F2 (C10-C16)			<20		mg/kg		20	25-AUG-18
F3 (C16-C34)			<20		mg/kg		20	25-AUG-18
F4 (C34-C50)			<20		mg/kg		20	25-AUG-18
Surrogate: 2-Bromobenzotrifluoride			88.1		%		70-130	25-AUG-18
F4G-TMB-ED	Soil							
Batch R4183957								
WG2860549-2 IRM		**ALS PHC2 RM**						
Gravimetric Heavy Hydrocarbons (Silica)			127.1		%		70-130	27-AUG-18
WG2860549-1 MB								
Gravimetric Heavy Hydrocarbons (Silica)			<500		mg/kg		500	27-AUG-18
HG-200.2-CVAA-ED	Soil							
Batch R4196180								
WG2865981-3 CRM		**TILL-1 SOIL**						
Mercury (Hg)			93.1		%		70-130	01-SEP-18
WG2865981-4 DUP		**L2152759-3**						
Mercury (Hg)		<0.0050	<0.0050	RPD-NA	mg/kg	N/A	40	01-SEP-18
WG2865981-2 LCS								
Mercury (Hg)			109.0		%		70-130	01-SEP-18
WG2865981-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	01-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R4196800								
WG2865981-3 CRM		**TILL-1_SOIL**						
Aluminum (Al)			105.7		%		70-130	03-SEP-18
Antimony (Sb)			112.0		%		70-130	03-SEP-18
Arsenic (As)			107.2		%		70-130	03-SEP-18
Barium (Ba)			103.0		%		70-130	03-SEP-18
Beryllium (Be)			110.7		%		70-130	03-SEP-18
Bismuth (Bi)			105.8		%		70-130	03-SEP-18
Boron (B)			3.8		mg/kg		0-8.2	03-SEP-18
Cadmium (Cd)			105.0		%		70-130	03-SEP-18
Calcium (Ca)			103.7		%		70-130	03-SEP-18
Chromium (Cr)			106.8		%		70-130	03-SEP-18
Cobalt (Co)			106.7		%		70-130	03-SEP-18
Copper (Cu)			108.0		%		70-130	03-SEP-18
Iron (Fe)			103.9		%		70-130	03-SEP-18
Lead (Pb)			107.1		%		70-130	03-SEP-18
Lithium (Li)			111.1		%		70-130	03-SEP-18
Magnesium (Mg)			105.5		%		70-130	03-SEP-18
Manganese (Mn)			102.4		%		70-130	03-SEP-18
Molybdenum (Mo)			107.6		%		70-130	03-SEP-18
Nickel (Ni)			106.9		%		70-130	03-SEP-18
Phosphorus (P)			104.4		%		70-130	03-SEP-18
Potassium (K)			104.7		%		70-130	03-SEP-18
Selenium (Se)			0.36		mg/kg		0.11-0.51	03-SEP-18
Silver (Ag)			0.26		mg/kg		0.13-0.33	03-SEP-18
Sodium (Na)			104.0		%		70-130	03-SEP-18
Strontium (Sr)			104.2		%		70-130	03-SEP-18
Thallium (Tl)			0.128		mg/kg		0.077-0.18	03-SEP-18
Tin (Sn)			1.0		mg/kg		0-3.1	03-SEP-18
Titanium (Ti)			98.4		%		70-130	03-SEP-18
Tungsten (W)			0.16		mg/kg		0-0.66	03-SEP-18
Uranium (U)			115.1		%		70-130	03-SEP-18
Vanadium (V)			106.0		%		70-130	03-SEP-18
Zinc (Zn)			106.7		%		70-130	03-SEP-18
Zirconium (Zr)			0.9		mg/kg		0-1.8	03-SEP-18
WG2865981-4 DUP		**L2152759-3**						

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R4196800								
WG2865981-4 DUP		**L2152759-3**						
Aluminum (Al)		394	465		mg/kg	17	40	03-SEP-18
Antimony (Sb)		<0.10	<0.10	RPD-NA	mg/kg	N/A	30	03-SEP-18
Arsenic (As)		0.36	0.42		mg/kg	15	30	03-SEP-18
Barium (Ba)		5.63	6.41		mg/kg	13	40	03-SEP-18
Beryllium (Be)		<0.10	<0.10	RPD-NA	mg/kg	N/A	30	03-SEP-18
Bismuth (Bi)		<0.20	<0.20	RPD-NA	mg/kg	N/A	30	03-SEP-18
Boron (B)		<5.0	<5.0	RPD-NA	mg/kg	N/A	30	03-SEP-18
Cadmium (Cd)		<0.020	<0.020	RPD-NA	mg/kg	N/A	30	03-SEP-18
Calcium (Ca)		3070	3080		mg/kg	0.2	30	03-SEP-18
Chromium (Cr)		1.07	1.54	J	mg/kg	0.47	1	03-SEP-18
Cobalt (Co)		0.42	0.51		mg/kg	20	30	03-SEP-18
Copper (Cu)		0.58	0.66		mg/kg	12	30	03-SEP-18
Iron (Fe)		1060	1960	DUP-H	mg/kg	59	30	03-SEP-18
Lead (Pb)		0.72	0.78		mg/kg	7.3	40	03-SEP-18
Lithium (Li)		<2.0	<2.0	RPD-NA	mg/kg	N/A	30	03-SEP-18
Magnesium (Mg)		960	850		mg/kg	12	30	03-SEP-18
Manganese (Mn)		36.6	42.3		mg/kg	14	30	03-SEP-18
Molybdenum (Mo)		<0.10	<0.10	RPD-NA	mg/kg	N/A	40	03-SEP-18
Nickel (Ni)		1.01	1.24		mg/kg	20	30	03-SEP-18
Phosphorus (P)		<50	<50	RPD-NA	mg/kg	N/A	30	03-SEP-18
Potassium (K)		<100	<100	RPD-NA	mg/kg	N/A	40	03-SEP-18
Selenium (Se)		<0.20	<0.20	RPD-NA	mg/kg	N/A	30	03-SEP-18
Silver (Ag)		<0.10	<0.10	RPD-NA	mg/kg	N/A	40	03-SEP-18
Sodium (Na)		<50	<50	RPD-NA	mg/kg	N/A	40	03-SEP-18
Strontium (Sr)		8.82	9.53		mg/kg	7.8	40	03-SEP-18
Sulfur (S)		<1000	<1000	RPD-NA	mg/kg	N/A	30	03-SEP-18
Thallium (Tl)		<0.050	<0.050	RPD-NA	mg/kg	N/A	30	03-SEP-18
Tin (Sn)		<2.0	<2.0	RPD-NA	mg/kg	N/A	40	03-SEP-18
Titanium (Ti)		15.6	22.6		mg/kg	36	40	03-SEP-18
Tungsten (W)		<0.50	<0.50	RPD-NA	mg/kg	N/A	30	03-SEP-18
Uranium (U)		0.070	0.087		mg/kg	22	30	03-SEP-18
Vanadium (V)		1.47	2.12	DUP-H	mg/kg	36	30	03-SEP-18
Zinc (Zn)		<2.0	2.2	RPD-NA	mg/kg	N/A	30	03-SEP-18
Zirconium (Zr)		1.1	1.4		mg/kg	24	30	03-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R4196800								
WG2865981-2 LCS								
Aluminum (Al)			102.3		%		80-120	03-SEP-18
Antimony (Sb)			107.5		%		80-120	03-SEP-18
Arsenic (As)			105.6		%		80-120	03-SEP-18
Barium (Ba)			104.0		%		80-120	03-SEP-18
Beryllium (Be)			99.9		%		80-120	03-SEP-18
Bismuth (Bi)			111.2		%		80-120	03-SEP-18
Boron (B)			93.9		%		80-120	03-SEP-18
Cadmium (Cd)			102.8		%		80-120	03-SEP-18
Calcium (Ca)			98.8		%		80-120	03-SEP-18
Chromium (Cr)			102.6		%		80-120	03-SEP-18
Cobalt (Co)			102.5		%		80-120	03-SEP-18
Copper (Cu)			99.9		%		80-120	03-SEP-18
Iron (Fe)			99.8		%		80-120	03-SEP-18
Lead (Pb)			102.3		%		80-120	03-SEP-18
Lithium (Li)			96.2		%		80-120	03-SEP-18
Magnesium (Mg)			103.4		%		80-120	03-SEP-18
Manganese (Mn)			100.9		%		80-120	03-SEP-18
Molybdenum (Mo)			102.7		%		80-120	03-SEP-18
Nickel (Ni)			102.7		%		80-120	03-SEP-18
Phosphorus (P)			106.9		%		80-120	03-SEP-18
Potassium (K)			106.1		%		80-120	03-SEP-18
Selenium (Se)			107.6		%		80-120	03-SEP-18
Silver (Ag)			111.7		%		80-120	03-SEP-18
Sodium (Na)			107.6		%		80-120	03-SEP-18
Strontium (Sr)			99.0		%		80-120	03-SEP-18
Sulfur (S)			101.4		%		80-120	03-SEP-18
Thallium (Tl)			101.8		%		80-120	03-SEP-18
Tin (Sn)			101.0		%		80-120	03-SEP-18
Titanium (Ti)			95.2		%		80-120	03-SEP-18
Tungsten (W)			103.1		%		80-120	03-SEP-18
Uranium (U)			106.9		%		80-120	03-SEP-18
Vanadium (V)			104.4		%		80-120	03-SEP-18
Zinc (Zn)			101.0		%		80-120	03-SEP-18
Zirconium (Zr)			99.3		%		80-120	03-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-ED	Soil							
Batch R4196800								
WG2865981-1 MB								
Aluminum (Al)			<50		mg/kg		50	03-SEP-18
Antimony (Sb)			<0.10		mg/kg		0.1	03-SEP-18
Arsenic (As)			<0.10		mg/kg		0.1	03-SEP-18
Barium (Ba)			<0.50		mg/kg		0.5	03-SEP-18
Beryllium (Be)			<0.10		mg/kg		0.1	03-SEP-18
Bismuth (Bi)			<0.20		mg/kg		0.2	03-SEP-18
Boron (B)			<5.0		mg/kg		5	03-SEP-18
Cadmium (Cd)			<0.020		mg/kg		0.02	03-SEP-18
Calcium (Ca)			<50		mg/kg		50	03-SEP-18
Chromium (Cr)			<0.50		mg/kg		0.5	03-SEP-18
Cobalt (Co)			<0.10		mg/kg		0.1	03-SEP-18
Copper (Cu)			<0.50		mg/kg		0.5	03-SEP-18
Iron (Fe)			<50		mg/kg		50	03-SEP-18
Lead (Pb)			<0.50		mg/kg		0.5	03-SEP-18
Lithium (Li)			<2.0		mg/kg		2	03-SEP-18
Magnesium (Mg)			<20		mg/kg		20	03-SEP-18
Manganese (Mn)			<1.0		mg/kg		1	03-SEP-18
Molybdenum (Mo)			<0.10		mg/kg		0.1	03-SEP-18
Nickel (Ni)			<0.50		mg/kg		0.5	03-SEP-18
Phosphorus (P)			<50		mg/kg		50	03-SEP-18
Potassium (K)			<100		mg/kg		100	03-SEP-18
Selenium (Se)			<0.20		mg/kg		0.2	03-SEP-18
Silver (Ag)			<0.10		mg/kg		0.1	03-SEP-18
Sodium (Na)			<50		mg/kg		50	03-SEP-18
Strontium (Sr)			<0.50		mg/kg		0.5	03-SEP-18
Sulfur (S)			<1000		mg/kg		1000	03-SEP-18
Thallium (Tl)			<0.050		mg/kg		0.05	03-SEP-18
Tin (Sn)			<2.0		mg/kg		2	03-SEP-18
Titanium (Ti)			<1.0		mg/kg		1	03-SEP-18
Tungsten (W)			<0.50		mg/kg		0.5	03-SEP-18
Uranium (U)			<0.050		mg/kg		0.05	03-SEP-18
Vanadium (V)			<0.20		mg/kg		0.2	03-SEP-18
Zinc (Zn)			<2.0		mg/kg		2	03-SEP-18
Zirconium (Zr)			<1.0		mg/kg		1	03-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-ALK-GCMS-CL	Soil							
Batch R4194849								
WG2864728-1 LCS								
Acenaphthene			82.4		%		60-130	30-AUG-18
Acenaphthylene			81.5		%		60-130	30-AUG-18
Acridine			73.3		%		60-130	30-AUG-18
Anthracene			66.0		%		60-130	30-AUG-18
Benz(a)anthracene			79.6		%		60-130	30-AUG-18
Benzo(a)pyrene			81.8		%		60-130	30-AUG-18
Perylene			84.3		%		60-130	30-AUG-18
Benzo(e)pyrene			82.1		%		60-130	30-AUG-18
Benzo(b&j)fluoranthene			79.5		%		60-130	30-AUG-18
Benzo(k)fluoranthene			82.8		%		60-130	30-AUG-18
Benzo(g,h,i)perylene			95.5		%		60-130	30-AUG-18
Biphenyl			77.8		%		60-130	30-AUG-18
C2 sub'd B(a)A/chrysene			83.4		%		50-150	30-AUG-18
C2 Benzofluoranthenes/Benzopyrenes			79.5		%		50-150	30-AUG-18
C2 Biphenyls			77.8		%		50-150	30-AUG-18
C2 Dibenzothiophenes			70.5		%		50-150	30-AUG-18
C2 Fluorenes			74.6		%		50-150	30-AUG-18
C2 Naphthalenes			91.5		%		50-150	30-AUG-18
C2 Phenanthrenes/Anthracenes			66.1		%		50-150	30-AUG-18
C3 Dibenzothiophenes			70.5		%		50-150	30-AUG-18
C3 Naphthalenes			91.5		%		50-150	30-AUG-18
C3 Phenanthrenes/Anthracenes			66.1		%		50-150	30-AUG-18
C4 Dibenzothiophenes			70.5		%		50-150	30-AUG-18
C4 Naphthalenes			91.5		%		50-150	30-AUG-18
C4 Phenanthrenes/Anthracenes			66.1		%		50-150	30-AUG-18
C3 Benzanthracenes/Chrysenes			83.4		%		50-150	30-AUG-18
C4 Benzanthracenes/Chrysenes			83.4		%		50-150	30-AUG-18
Chrysene			83.4		%		60-130	30-AUG-18
Dibenz(a,h)anthracene			91.8		%		60-130	30-AUG-18
Dibenzothiophene			70.5		%		60-130	30-AUG-18
Fluoranthene			78.7		%		60-130	30-AUG-18
Fluorene			74.6		%		60-130	30-AUG-18
Indeno(1,2,3-cd)pyrene			93.3		%		60-130	30-AUG-18
C1 Benz(a)Anthracenes/Chrysenes			83.4		%		60-130	30-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-ALK-GCMS-CL	Soil							
Batch R4194849								
WG2864728-1 LCS								
C1 Benzofluoranthenes/Benzopyrenes			79.5		%		60-130	30-AUG-18
C1 Acenaphthenes			82.4		%		60-130	30-AUG-18
C1 Biphenyls			77.8		%		60-130	30-AUG-18
C1 Dibenzothiophenes			70.5		%		60-130	30-AUG-18
C1 Fluoranthenes/Pyrenes			78.7		%		60-130	30-AUG-18
C1 Fluorenes			74.6		%		60-130	30-AUG-18
1-Methylnaphthalene			85.1		%		50-130	30-AUG-18
2-Methylnaphthalene			83.8		%		50-130	30-AUG-18
C1 Phenanthrenes/Anthracenes			66.1		%		60-130	30-AUG-18
Naphthalene			91.5		%		50-130	30-AUG-18
Phenanthrene			66.1		%		60-130	30-AUG-18
Pyrene			78.6		%		60-130	30-AUG-18
Quinoline			87.0		%		60-130	30-AUG-18
C2 Fluoranthenes/Pyrenes			78.7		%		50-150	30-AUG-18
C3 Fluoranthenes/Pyrenes			78.7		%		50-150	30-AUG-18
C3 Fluorenes			74.6		%		50-150	30-AUG-18
C4 Fluoranthenes/Pyrenes			78.7		%		50-150	30-AUG-18
Retene			82.2		%		60-130	30-AUG-18
WG2864728-2 MB								
Acenaphthene			<0.0050		mg/kg		0.005	30-AUG-18
Acenaphthylene			<0.0050		mg/kg		0.005	30-AUG-18
Acridine			<0.010		mg/kg		0.01	30-AUG-18
Anthracene			<0.0040		mg/kg		0.004	30-AUG-18
Benz(a)anthracene			<0.010		mg/kg		0.01	30-AUG-18
Benzo(a)pyrene			<0.010		mg/kg		0.01	30-AUG-18
Perylene			<0.010		mg/kg		0.01	30-AUG-18
Benzo(e)pyrene			<0.010		mg/kg		0.01	30-AUG-18
Benzo(b&j)fluoranthene			<0.010		mg/kg		0.01	30-AUG-18
Benzo(k)fluoranthene			<0.010		mg/kg		0.01	30-AUG-18
Benzo(g,h,i)perylene			<0.010		mg/kg		0.01	30-AUG-18
Biphenyl			<0.010		mg/kg		0.01	30-AUG-18
C2 sub'd B(a)A/chrysene			<0.040		mg/kg		0.04	30-AUG-18
C2 Benzofluoranthenes/Benzopyrenes			<0.040		mg/kg		0.04	30-AUG-18
C2 Biphenyls			<0.040		mg/kg		0.04	30-AUG-18

ALS Environmental

Quality Control Report

Workorder: L2152759 Report Date: 10-SEP-18

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-ALK-GCMS-CL	Soil							
Batch R4194849								
WG2864728-2 MB								
C2 Dibenzothiophenes			<0.040		mg/kg		0.04	30-AUG-18
C2 Fluorenes			<0.040		mg/kg		0.04	30-AUG-18
C2 Naphthalenes			<0.040		mg/kg		0.04	30-AUG-18
C2 Phenanthrenes/Anthracenes			<0.040		mg/kg		0.04	30-AUG-18
C3 Dibenzothiophenes			<0.040		mg/kg		0.04	30-AUG-18
C3 Naphthalenes			<0.040		mg/kg		0.04	30-AUG-18
C3 Phenanthrenes/Anthracenes			<0.040		mg/kg		0.04	30-AUG-18
C4 Dibenzothiophenes			<0.040		mg/kg		0.04	30-AUG-18
C4 Naphthalenes			<0.040		mg/kg		0.04	30-AUG-18
C4 Phenanthrenes/Anthracenes			<0.040		mg/kg		0.04	30-AUG-18
C3 Benzanthracenes/Chrysenes			<0.040		mg/kg		0.04	30-AUG-18
C4 Benzanthracenes/Chrysenes			<0.040		mg/kg		0.04	30-AUG-18
Chrysene			<0.010		mg/kg		0.01	30-AUG-18
Dibenz(a,h)anthracene			<0.0050		mg/kg		0.005	30-AUG-18
Dibenzothiophene			<0.010		mg/kg		0.01	30-AUG-18
Fluoranthene			<0.010		mg/kg		0.01	30-AUG-18
Fluorene			<0.010		mg/kg		0.01	30-AUG-18
Indeno(1,2,3-cd)pyrene			<0.010		mg/kg		0.01	30-AUG-18
C1 Benz(a)Anthracenes/Chrysenes			<0.040		mg/kg		0.04	30-AUG-18
C1 Benzofluoranthenes/Benzopyrenes			<0.040		mg/kg		0.04	30-AUG-18
C1 Acenaphthenes			<0.040		mg/kg		0.04	30-AUG-18
C1 Biphenyls			<0.040		mg/kg		0.04	30-AUG-18
C1 Dibenzothiophenes			<0.040		mg/kg		0.04	30-AUG-18
C1 Fluoranthenes/Pyrenes			<0.040		mg/kg		0.04	30-AUG-18
C1 Fluorenes			<0.040		mg/kg		0.04	30-AUG-18
1-Methylnaphthalene			<0.010		mg/kg		0.01	30-AUG-18
2-Methylnaphthalene			<0.010		mg/kg		0.01	30-AUG-18
C1 Phenanthrenes/Anthracenes			<0.040		mg/kg		0.04	30-AUG-18
Naphthalene			<0.010		mg/kg		0.01	30-AUG-18
Phenanthrene			<0.010		mg/kg		0.01	30-AUG-18
Pyrene			<0.010		mg/kg		0.01	30-AUG-18
Quinoline			<0.010		mg/kg		0.01	30-AUG-18
C2 Fluoranthenes/Pyrenes			<0.040		mg/kg		0.04	30-AUG-18
C3 Fluoranthenes/Pyrenes			<0.040		mg/kg		0.04	30-AUG-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PAH-ALK-GCMS-CL	Soil							
Batch R4194849								
WG2864728-2 MB								
C3 Fluorenes			<0.040		mg/kg		0.04	30-AUG-18
C4 Fluoranthenes/Pyrenes			<0.040		mg/kg		0.04	30-AUG-18
Retene			<0.010		mg/kg		0.01	30-AUG-18
Surrogate: d10-Acenaphthene			92.5		%		50-140	30-AUG-18
Surrogate: d12-Chrysene			92.3		%		50-140	30-AUG-18
Surrogate: d8-Naphthalene			106.8		%		50-140	30-AUG-18
Surrogate: d10-Phenanthrene			80.7		%		50-140	30-AUG-18
PREP-MOISTURE-ED	Soil							
Batch R4183066								
WG2859912-2 LCS								
% Moisture			100.2		%		90-110	25-AUG-18
WG2859912-1 MB								
% Moisture			<0.50		%		0.5	25-AUG-18
PSA-1-ED	Soil							
Batch R4192391								
WG2862077-2 IRM		**SALINITY_SOIL6**						
% Sand			40.4		%		36.4-46.4	29-AUG-18
% Silt			32.4		%		26.4-36.4	29-AUG-18
% Clay			27.2		%		22.1-32.1	29-AUG-18
WG2862077-1 MB								
% Sand			<1.0		%		1	29-AUG-18
% Silt			<1.0		%		1	29-AUG-18
% Clay			<1.0		%		1	29-AUG-18
PSA-3-SK	Soil							
Batch R4205338								
WG2862868-1 DUP		**L2152759-3**						
% Sand (2.0mm - 0.05mm)		96.9	96.9	J	%	0.0	10	07-SEP-18
% Silt (0.05mm - 2um)		2.6	2.3	J	%	0.3	10	07-SEP-18
% Clay (<2um)		<1.0	<1.0	RPD-NA	%	N/A	10	07-SEP-18
WG2862868-2 IRM		**2017-PSA**						
% Sand (2.0mm - 0.05mm)			50.2		%		38-58	07-SEP-18
% Silt (0.05mm - 2um)			42.4		%		25-45	07-SEP-18
% Clay (<2um)			7.4		%		7-27	07-SEP-18
WG2862868-3 MB								
% Sand (2.0mm - 0.05mm)			99.9		%		105	07-SEP-18

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PSA-3-SK	Soil							
Batch R4205338								
WG2862868-3 MB								
% Silt (0.05mm - 2um)			<1.0		%		1	07-SEP-18
% Clay (<2um)			<1.0		%		1	07-SEP-18

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DUP-H	Duplicate results outside ALS DQO, due to sample heterogeneity.
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

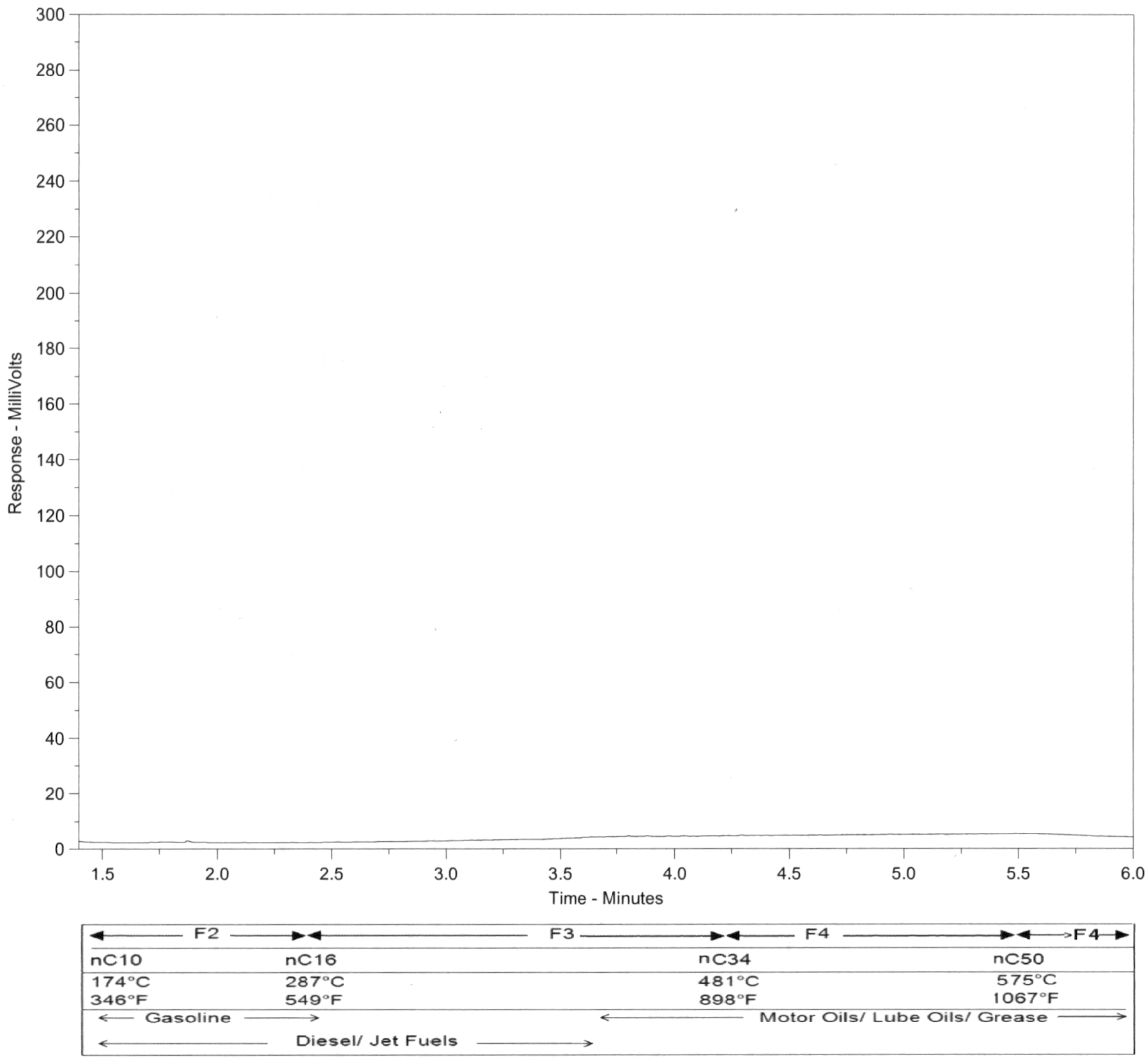
ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Hydrocarbon Distribution Report

ALS Sample ID: L2152759-1
Client ID: PZ-1



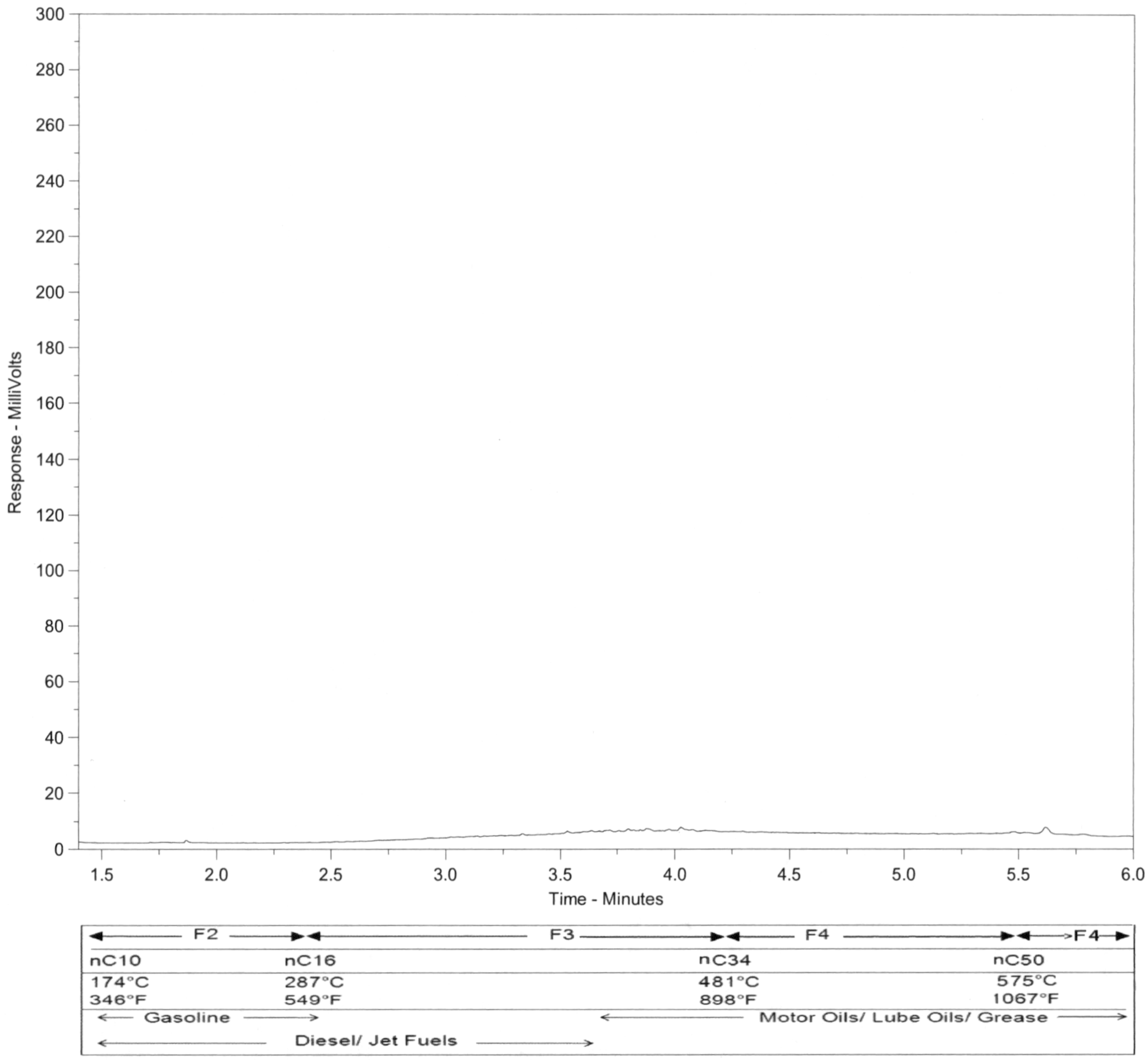
The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

Hydrocarbon Distribution Report

ALS Sample ID: L2152759-2
Client ID: IC-1



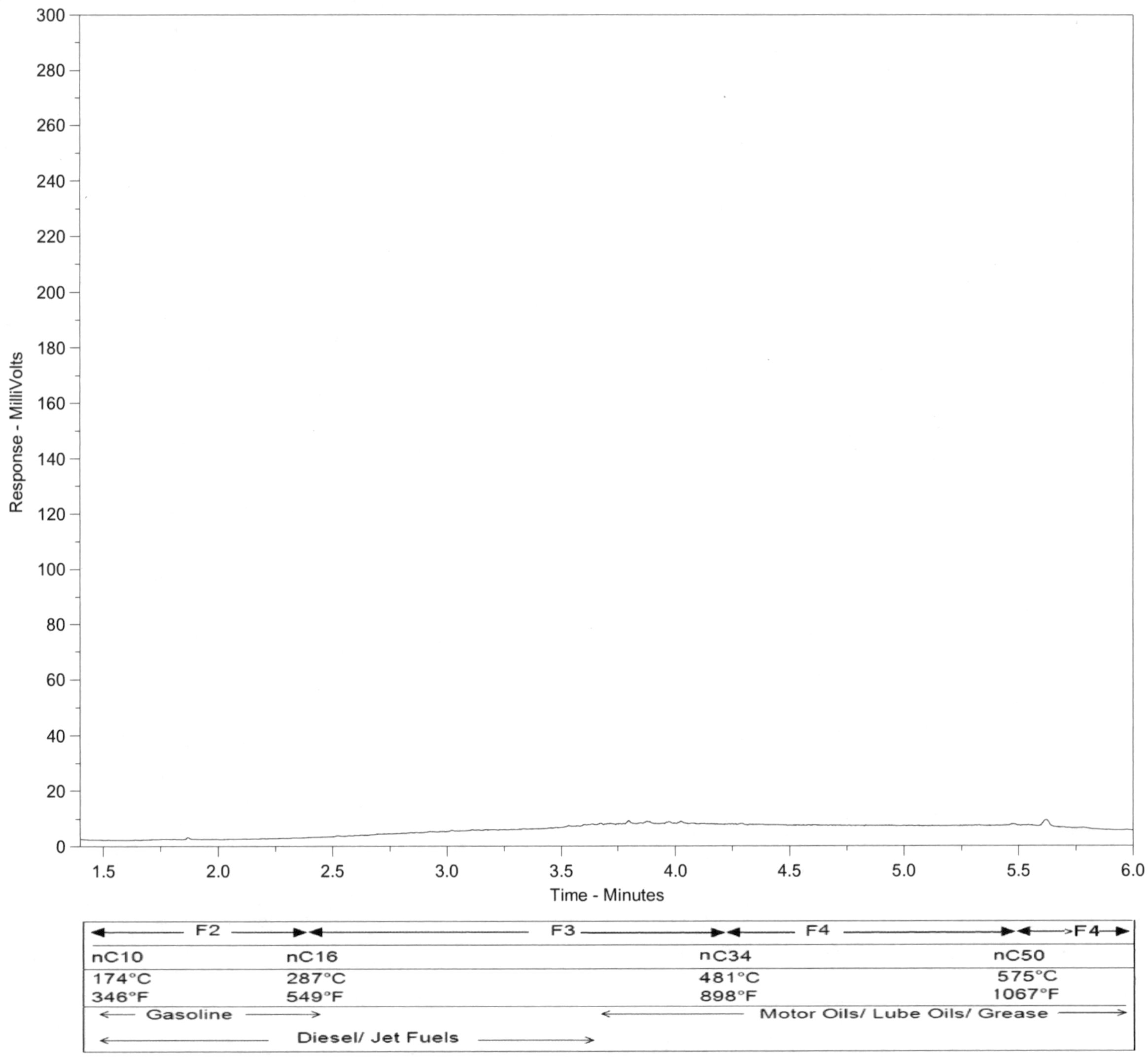
The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

Hydrocarbon Distribution Report

ALS Sample ID: L2152759-3
Client ID: LZ-COMP



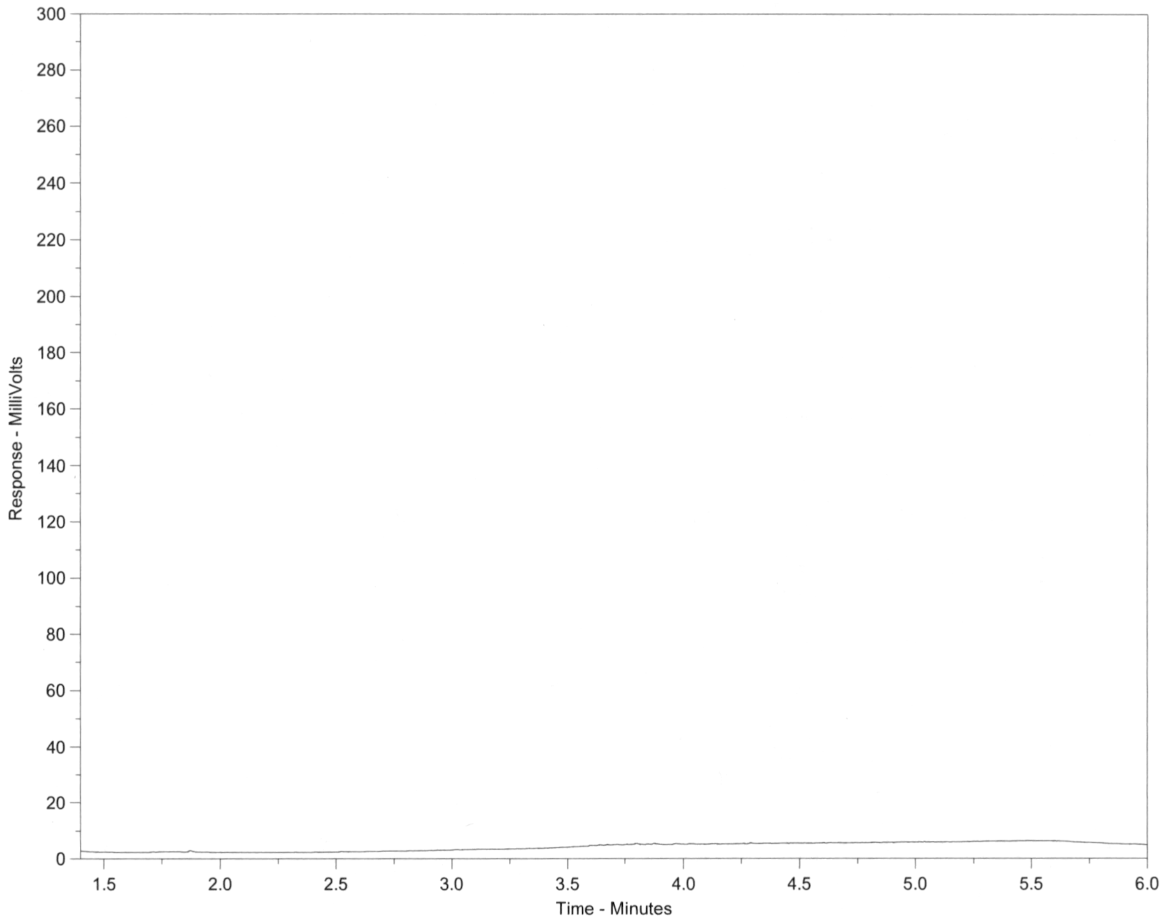
The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

Hydrocarbon Distribution Report

ALS Sample ID: L2152759-4
Client ID: SP-1



F2		F3	F4	F4
nC10	nC16	nC34	nC50	
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F	
← Gasoline →		← Motor Oils/ Lube Oils/ Grease →		
← Diesel/ Jet Fuels →				

The Canada Wide Standard Hydrocarbon Distribution Report is intended to assist you in characterizing hydrocarbon products that may be present in your sample. The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products as well as a number of specified n-alkane hydrocarbon marker compounds. Comparison of this report with those of reference standards may also assist in characterizing hydrocarbons present in the sample.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note:
This chromatogram was produced with a high temperature GC method that is specific to the Canada-Wide Standard method. Note that retention times and distribution profiles from reports produced using different GC programs will differ.

s.19(1)

ALS

www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

COC Number: L2152759-COFC

Report To

Company:	Hatfield Consultants
Contact:	Chris Jaeggle/Andrew O'Gorman
Address:	200-850 Harbourside Drive North Vancouver, BC V7P 0A3
Phone:	780-743-4290/604-926-3261

Report Format / Distribution

Select Report Format: ☑ PDF ☑ EXCEL ☑ EDD (DIGITAL)

Quality Control (QC) Report with Report ☑ Yes ☐ No

☐ Criteria on Report - provide details below if box checked

Select Distribution: ☑ EMAIL ☐ MAIL ☐ FAX

Email or Fax

Email

Email

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)

- R ☑ Regular (Standard TAT if received by 3 pm - business days)
- P ☐ Priority (2-4 bus. days if received by 3pm) 50% surcharge - contact ALS to confirm TAT
- E ☐ Emergency (1-2 bus. days if received by 3pm) 100% surcharge - contact ALS to confirm TAT
- E2 ☐ Same day or weekend emergency - contact ALS to confirm TAT and surcharge

Specify Date Required for E2,E or P:

Invoice To

Same as Report To ☑ Yes ☐ No

Copy of Invoice with Report ☑ Yes ☐ No

Company:

Contact:

Invoice Distribution

Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX

Email 1

Email 2

Project Information

ALS Quote #:	Q29294
Job #:	CNUL9184
PO / AFE:	
LSD:	

Oil and Gas Required Fields (client use)

Approver ID:	Cost Center:
GL Account:	Routing Code:
Activity Code:	
Location:	

ALS Lab Work Order # (lab use only)

ALS Contact:

Sampler: AC / AJ

Analysis Request

Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Q29294	Number of Containers
	PZ-1	23-Aug-18	9:17	Sediment	X	6
	IC-1	23-Aug-18	15:10	Sediment	X	6
	LZ-Comp	23-Aug-18	13:10	Sediment	X	6
	SP-1	23-Aug-18	9:17	Sediment	X	6

P/A ice / ice packs
P/A free water

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System? ☐ Yes ☒ No

Are samples for human drinking water use? ☐ Yes ☒ No

Special Instructions / Specify Criteria to add on report (client Use)

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐

Ice packs Yes ☐ No ☐ Custody seal intact Yes ☐ No ☐

Cooling Initiated ☐

INITIAL COOLER TEMPERATURES °C: 3°C

FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by:	Date: 24 Aug 18	Time: 10:55	Received by: AD	Date: 08/24/18	Time: 10:35 A	Received by:	Date:	Time:

REFER TO BAC[...]E FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

NA-FM-0326e v09 Front/04 January 2014

Failure to complete [...]ons of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a **Regulated Drinking Water (DW) System**, please submit using an **Authorized DW COC form**.

Appendix A5

Station Information Sheets

Hatfield CONSULTANTS

Mrs. T's Lake & Inlet Channel

IC1/LL-1

Station Information Sheet

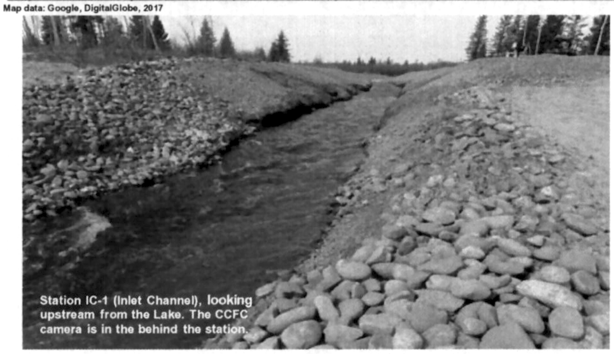
Revised: 26 February 2019

Location and Purpose:

Established to monitor discharge inputs from Muskeg River, along the Inlet Channel, to Mrs. T's Lake, as well as the water levels on the Lake. The purpose of this station is to monitor diversions from the Muskeg River, provide data to calculate water balances for the Lake, and to provide insight into fish habitat and fish passage both in the Lake, and between the Muskeg River. The station is located approximately 4 km NW of the CNRL Albian Village camp. Operation of this station started in 2016.



Map data: Google, DigitalGlobe, 2017



Station IC-1 (Inlet Channel), looking upstream from the Lake. The CCFC camera is in the behind the station.



Station IC-1 (Inlet Channel), looking cross channel and towards the Lake. The CCFC camera is to the right of the station.

Station Details

Variables Measured:	Discharge, water level, water temperature
Period of Record:	June 2016 to present
Station Operation:	Year Round
Access:	Truck via CNRL Jackpine Mine - IOL Road, Boat from picnic area to station
Drainage Area:	N/A
UTM Coordinates:	472096 E, 6347404 N (NAD83)
Lat/Long:	56°14'8" N, 111°27'45" W (NAD83)

Measurement Details:

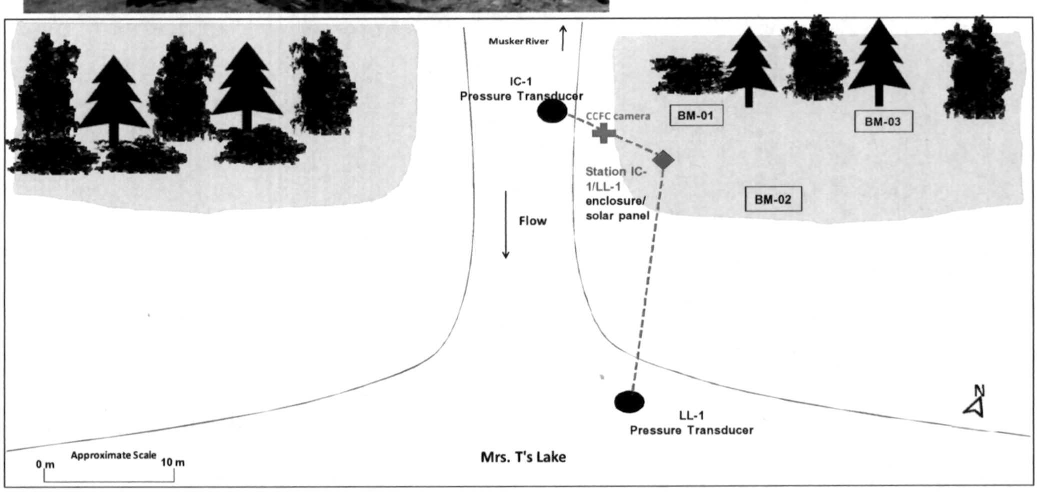
Channel:	The channel is approx. 5 m wide, with trapezoidal edges. The bed substrate is comprised of cobbles.
Control:	Backwater from the Lake and channel control within the reach
Metering Section:	The metering section is located adjacent to the gauge, and the channel can likely be waded at all water levels.

Station Equipment

Datalogger:	Campbell Scientific CR1000
Water Level Sensor:	Ott PLS 0-4m range, 15 m cable in the channel and a levelogger in the lake. The lake logger was strapped to 10 lb weight and placed on the lake bottom. The channel logger was strapped to a 25lb weight with an anchor line and placed on the channel bed
Power Supply:	12V 20ah sealed lead acid battery, 2 x 20W solar panel, solar charge controller
Station Mast & Enclosure:	Campbell Scientific 12x14" enclosure attached to steel mast next to Inlet Channel

Benchmark Information

BM:	BM-01
Elevation:	281.080
Basis:	Geodetic Survey in 2016
Location:	3 m West of staton
Description:	0.75" steel rod driven to refusal
BM:	BM-02
Elevation:	280.094
Basis:	Level Survey from BM-01
Location:	25 m from lake
Description:	Bolt in tree
BM:	BM-03
Elevation:	281.094
Basis:	Level Survey from BM-01
Location:	30m from lake
Description:	Bolt in tree



Hatfield CONSULTANTS

Muskeg River Upstream of the Lake Outlet Channel

Revised: 26 February 2019

MR-D

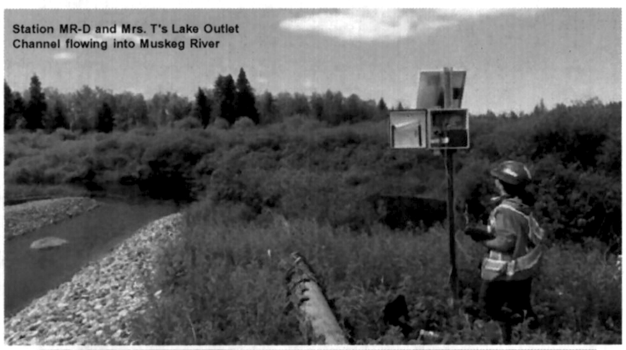
Station Information Sheet

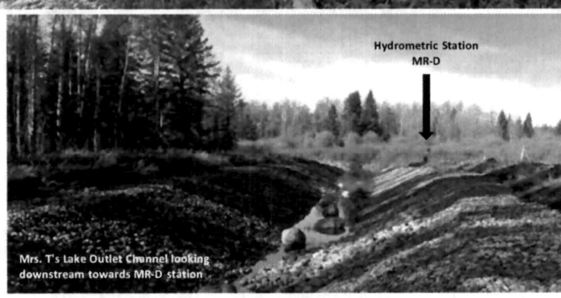
Location and Purpose:

This station was established to monitor water levels on the Muskeg River just upstream of the Lake Outlet confluence. Its purpose is to provide insight into backwater effects of the Outlet Channel on the Muskeg River, to ensure that the Outlet Channel functions properly and flow does not divert from the river to the lake. The station is located approximately 4km NW of CNRL Albian Village. Operation of this station started on April 12, 2017.



Map Based on Google Earth Image





Station Details

Variables Measured:	Water level, water temperature
Period of Record:	12-Apr-17
Station Operation:	Year Round
Access:	Cannera Road
Drainage Area:	approximately 923 km²
UTM Coordinates:	471587 E, 6346641 N (NAD83)
Lat/Long:	57°15'43" N, 111°28'16" W (NAD83)

Measurement Details:

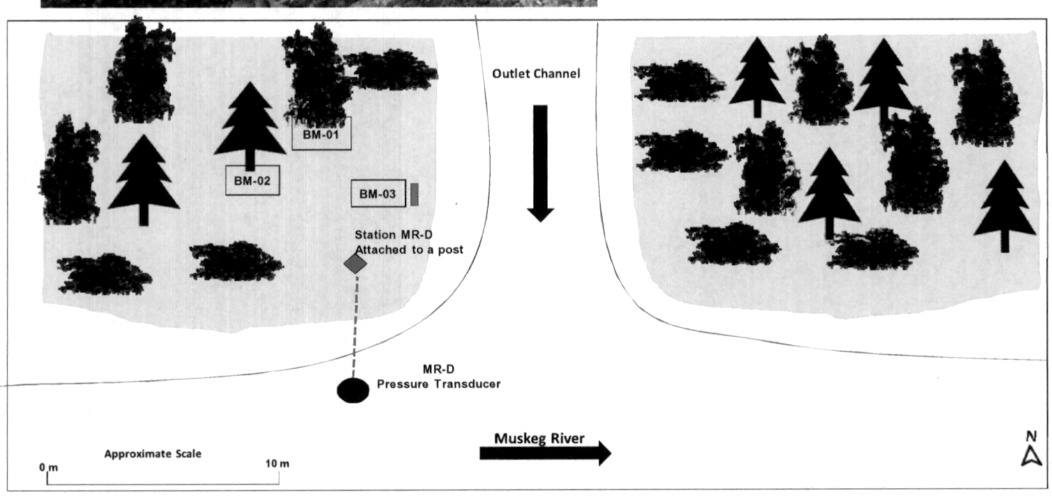
Channel:	The channel is approximately 12 m wide, with trapezoidal edges. The bed substrate is comprised of sand, silt and cobbles.
Control:	Downstream channel control and the confluence of Muskeg River and Jackpine Creek.

Station Equipment

Datalogger:	Campbell Scientific CR800
Water Level Sensor:	Ott PLS 0-4m range, 15 m cable. Transducer strapped to 10 lb weight on river channel bottom, anchored to mast.
Power Supply:	12V 20ah sealed lead acid battery, 20W solar panel, solar charge controller
Station Mast & Enclosure:	6' steel sign post driven into ground with Campbell Scientific 12x14" enclosure u-bolted to mast

Benchmark Information

BM:	BM-01
Elevation:	280.497
Basis:	Level survey from BM-03
Location:	40 m north of staton
Description:	Bolt in deciduous tree
BM:	BM-02
Elevation:	280.314
Basis:	Level survey from BM-03
Location:	30 m north of station
Description:	Bolt in coniferous tree
BM:	BM-03
Elevation:	281.580
Basis:	Geodetic survey in 2016
Location:	15 m north of station
Description:	0.75" steel rod driven to refusal



Hatfield CONSULTANTS

Muskeg River at the Lake Inlet Channel

MR-U
Station Information Sheet

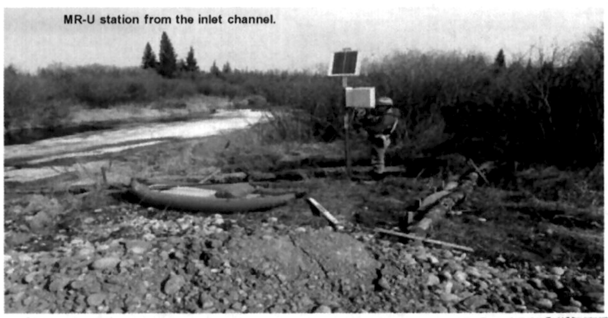
Revised: 26 February 2019

Location and Purpose:

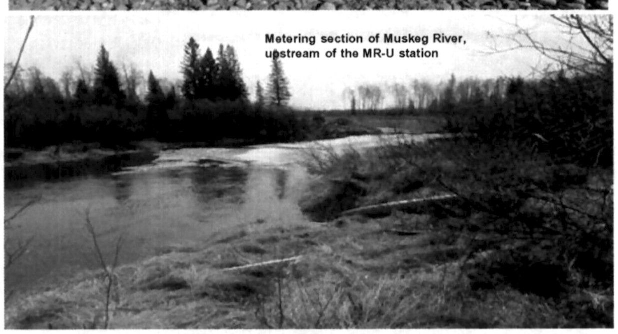
Established to monitor discharge in the Muskeg River at the Mrs. T's Lake Inlet. This station is intended to provide information to calculate water balances of Mrs. T's Lake and quantify effects of the Lake on the hydrology of Muskeg River. The station is located approximately 4km NW of CNRL Albian Village. Operation of this station started on April 12, 2017.



Map Based on Google Earth Image



MR-U station from the inlet channel.



Metering section of Muskeg River, upstream of the MR-U station

Station Details

Variables Measured:	Discharge, water level, water temperature
Period of Record:	April 12, 2017 to present
Station Operation:	Year Round
Access:	Truck via CNRL Jackpine Mine - IOL Road, Boat from picnic area to station
Drainage Area:	919 km²
UTM Coordinates:	472041 E, 6347491 N (NAD83)
Lat/Long:	57°16'11" N, 111°27'49" W (NAD83)

Measurement Details:

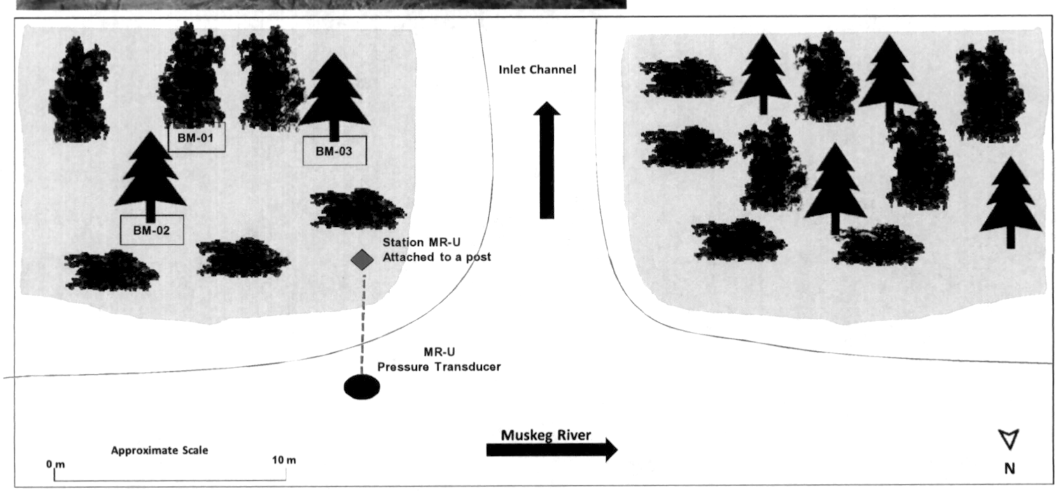
Channel:	The channel is approximately 15 m wide, with trapezoidal edges. The bed substrate is comprised of sand, silt and cobbles.
Control:	Channel controls within the cross-section and downstream constrictions
Metering Section:	The metering section is located upstream of the gauging station. Measurements can be completed using an ADCP or an ADV during low flow conditions.

Station Equipment

Datalogger:	Campbell Scientific CR1000
Water Level Sensor:	Ott PLS 0-4m range, 15 m cable. Transducer strapped to 10 lb weight on river channel bottom, anchored to mast.
Power Supply:	12V 20ah sealed lead acid battery, 20W solar panel, solar charge controller
Station Mast & Enclosure:	6' steel sign post driven into ground with Campbell Scientific 12x14" enclosure u-bolted to mast

Benchmark Information

BM:	BM-01
Elevation:	280.973
Basis:	Level survey from IC1/LL-1 BM-01
Location:	25 m south east of staton
Description:	Lag bolt in conifer
BM:	BM-02
Elevation:	280.931
Basis:	Level survey from IC1/LL-1 BM-01
Location:	15 m east of station
Description:	Bolt in conifer
BM:	BM-03
Elevation:	281.010
Basis:	Level survey from IC1/LL-1 BM-01
Location:	15m south of station
Description:	Bolt in conifer



Hatfield CONSULTANTS

Mrs. T's Lake Outlet Channel

OC-1

Station Information Sheet

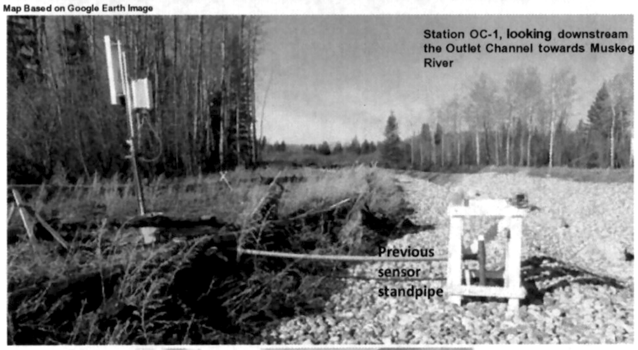
Revised: 26 February 2019

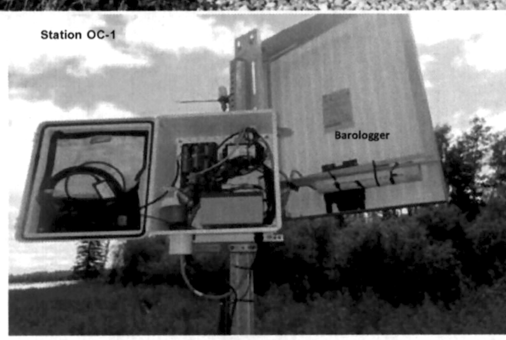
Location and Purpose:

Established to monitor outflow from Mrs. T's Lake to Muskeg River to provide insight into the lake water balance and fish passage between the lake and Muskeg River. The station is located approximately 4 km NW of CNRL Albian Village. Operation of this station started in 2016.



Map Based on Google Earth Image





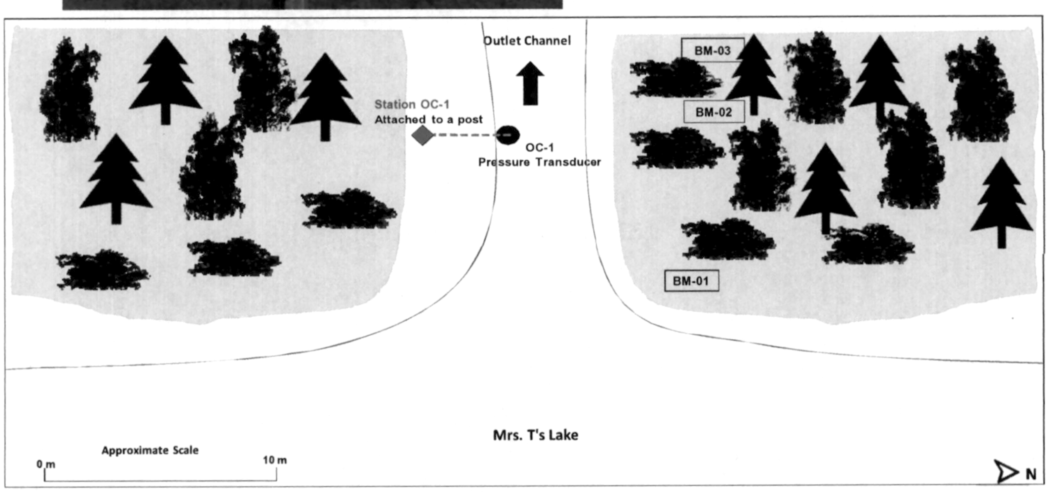
Station Details	
Variables Measured:	Discharge, water level, water temperature
Period of Record:	2016 to present
Station Operation:	Year round
Access:	Truck via CNRL Jackpine Mine - IOL Road, Boat from picnic area to station
Drainage Area:	N/A
UTM Coordinates:	471709 E, 6346702 N (NAD83)
Lat/Long:	57°15'45" N, 111°28'9" W (NAD83)

Measurement Details:	
Channel:	The channel is approximately 10 m wide, with trapezoidal edges. The bed substrate is comprised of cobbles and large boulders.
Control:	Upstream lake levels
Metering Section:	The metering section is located adjacent to the gauging station. The channel is likely wadable at most water levels

Station Equipment	
Datalogger:	Campbell Scientific CR1000
Water Level Sensor:	OTT PLS attached to a 25 lb weight and anchored . Barologger strapped to back of solar panel.
Power Supply:	12V 20ah sealed lead acid battery, 20W solar panel, solar charge controller
Station Mast & Enclosure:	6' steel sign post driven into ground with Campbell Scientific 12x14" enclosure u-bolted to mast

Benchmark Information

BM:	BM-01
Elevation:	280.760
Basis:	2016 Geodetic survey
Location:	60m East of OC-1 station on opposite bank
Description:	0.75" steel rod driven to refusal
BM:	BM-2
Elevation:	280.120
Basis:	Level survey of BM-01
Location:	20m northwest of OC-1 on opposite bank
Description:	Upstream lag bolt in tree
BM:	BM-3
Elevation:	280.063
Basis:	Level survey of BM-01
Location:	20m northwest of OC-1 station on opposite bank
Description:	Downstream lag bolt in tree



Hatfield CONSULTANTS

Mrs. T's Lake Pelagic Zone Buoy

PZ1
Station Information Sheet

Revised: 1 March 2019

Location and Purpose:
Established to monitor continuous water quality in Mrs. T's Lake to provide insight into the water quality at various depths and changes throughout the open water season. The buoy is located approximately 4 km NW of CNRL Albian Village in the middle of the Lake. Operation of this monitoring buoy started in 2018.



Map Based on Google Earth Image

Station Details	
Variables Measured:	Continuous water quality: water temperature, light intensity, specific conductivity, pH, dissolved oxygen
Period of Record:	2018 to present
Station Operation:	Open-water (May-October)
Access:	Truck via CNRL Jackpine Mine - IOL Road, Boat from picnic area to buoy
UTM Coordinates:	4727115 E, 6346958 N (NAD83)
Lat/Long:	57°15'51" N, 111°27'45" W (NAD83)
Buoy Equipment Details	
Buoy Location	The lake depth at the buoy location is approximately 12 m. The lake bed substrate is composed primarily of sand and fine silt. Buoy is anchored to bottom of the lake. Sondes and thermostring sensors are affixed to buoy via cables.
Continuous Water Quality Sensors:	Three YSI EXO3 data sondes, deployed at 0.5 m, 6 m, and 11 m below the Lake surface. Sondes measure water temperature, specific conductivity, pH, and dissolved oxygen
Continuous Water Temperature and Light Penetration Sensors:	HOBO Pendant light/temperature 64k (thermostring), sensors deployed at 0.5, 2, 3, 4, 5, 7, 8, 9, and 10 m from Lake surface

